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JULY 1982

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OFFICE OF NOISE ABATEMENT AND CONTROL
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For many airports, a residual population imported by aircraft noise will remain after benefits from all other noise control means have been realized. This report considers residential soundproofing and relocation programs as a means of achieving airport noise/land use compatibility. A detailed discussion of issues involved in such a program is given. To quantify the cost of such a program a methodolgy is developed and used to integrate parameters affecting noise exposure. A forecast is presented of changes in air carrier airport noise exposure that will occur during the balance of this century. The study also examines the noise exposure benefit of noise abatement flight operations, flight procedure, and restrictions on population encroachment. Soundproofing and relocation costs are developed for four airports.

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FOR THE:

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U.S. ENVIRONMENTAL PROTECTION AGENCY
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I. INTRODUCTION AND SUMMARY

The concern with airport noise has led to a number of major steps to reduce exposure levels. Tangible benefits of these steps are evident today. Quieter aircraft are now operating in the U.S. fleet, adjusted flight procedures result in some aircraft being flown in a quieter manner, some airport operations are geared to appropriate flight tracks and airport proprietors and local officials are carrying out noise abatement actions at particular airports. The result of these actions has been a reduction in the number of people exposed to high levels of noise from aircraft operations. Further reductions in exposure will occur during the balance of this century as the federal noise regulations which have been promulgated become fully effective.

For many airports, a residual population impacted by aircraft noise will remain after benefits from all other noise control means have been realized. This report considers a residential soundproofing and relocation program as a means of achieving airport noise/land use compatibility. A detailed discussion of issues involved in such a program is given. To quantify the cost of such a program a methodology is developed and used to integrate parameters affecting noise exposure. A forecast is presented of changes in air carrier airport noise exposure that will occur during the balance of this century. This study also examines noise exposure benefits of noise abatement flight operations, flight procedures, and restrictions on population encroachment. Soundproofing and relocation costs are developed for four airports.

PART 150 PLANNING PROGRAM

A major new program was recently established to promote a planning program to develop compatibility of aircraft noise with land-use near airports. Specifically, the Federal Aviation Administration (FAA) on January 6, 1981, established interim regulations prescribing requirements for airport operators who choose to develop an airport noise compatibility planning program. This program, codified at 14 CFR Part 150 (hereinafter Part 150), establishes a single system of measuring airport noise and a single system for determining the exposure of individuals to aircraft noise. A standardized airport noise compatiblity planning procedure also is prescribed. The compatibility program seeks to obtain compatibility of aircraft operations with community activities within acceptable safety, economic and environmental parameters. This may be accomplished by reducing existing incompatible land use in the vicinity of a particular airport and by preventing the introduction of new incompatible land uses in the future.

Each airport program developed under Part 150 must address noise control alternatives, subject to the constraint that the alternative strategy be appropriate to a specific airport, including the following:

- Preferential runway system
- Construction of barriers and acoustical shielding, including the soundproofing of public buildings
- Restrictions on the use of the airport by any type or class of aircraft based on aircraft noise characteristics (such as curfews, noise abatement takeoff approach procedures and landing fees)
- Flight procedures to reduce noise exposure
- Acquisition of land and interest therein to insure airport compatible land uses.

The noise control alternatives no doubt will help improve the noise environment at airports and, more specifically, generate added confidence that the estimates of people exposed will be reduced in future years. However, the noise "problem" and its related effects on air carrier operations will continue until compatibility is achieved. Statistics that demonstrate reduced noise exposure 20 years hence may provide little solace to people who currently, or in the near to mid-term, will live in areas of unacceptably high airport noise levels. But some encouragement may be derived from a land use change program if the most heavily impacted areas are treated in the near future.

The Part 150 planning process requires that incompatibilities be identified and plans be included for their elimination. This could include, after reasonable noise control alternatives are implemented, a program of soundproofing and relocating private residences exposed to airport noise levels exceeding L_{dn} 65 dB and 75 dB, respectively. The objective of Part 150 is to establish a maximum outdoor level of L_{dn} 65 dB to assure compatibility with Federal criterion. When L_{dn} 65 dB cannot be reasonably met, soundproofing could provide an acceptable level of indoor noise and, if outdoor noise cannot be reduced to L_{dn} 75 dB, the opportunity to be relocated.

Soundproofing and relocation are certainly not new noise control measures. Both have been employed in selected circumstances in the United States and abroad. However, there is extant relatively minimal experience with a comprehensive relocation/soundproofing program, particularly in conjunction with broader, more comprehensive airport noise control planning processes.

With this in mind, subsequent chapters of this report analyze issues (Chapter II) and present background material (Chapters III and IV) relevant to the planning for and implementation of a comprehensive airport soundproofing/relocation program. To place the various issues and background material in a proper perspective, scenarios concerning the level of noise exposure and attendant program implementation costs are developed. Guiding the development of these scenarios are four general assumptions:

- All private residences within specified noise contours (i.e., L_{dn} 65 to 75 dB and, as an option L_{dn} 75 to 80 dB) will be candidates for soundproofing assistance
- All private residences within other higher specified noise contours (i.e., greater than L_{dn} 75 dB (or L_{dn} 80 dB) will be candidates for relocation assistance
- The program should apply to residences exposed to specified noise contours projected for the year 2000
- The concept of representative airports, or "Reports" will be used to assess program issues and costs which might be faced by airports interested in this program.

SELECTION OF REPRESENTATIVE AIRPORTS

The concept of and procedure to select representative airports, or Rports, are described in Chapter III. In general, each representative airport represents a distinct category of airports specified in terms of area and population exposed to adverse noise levels. Airports included in the Rport selection process were limited in the first instance to those with scheduled commercial jet operations (398 airports). The universe was further restricted by excluding airports with less than four air carrier jet operations per day, as less than four flights would not constitute a noise problem. Factor analysis was then used to group the remaining 326 airports into six distinct Rport categories. Within each category, a single airport was sought which, on average, represented the noise exposure characteristics of all other airports in that category. However, for two of the categories no such representative airport could be found and representative airports were not selected. The remaining four categories for which Rports were selected contained 129 airports and accounted for 62 percent of the 1979 national departures.*

The four representative airports used in this study are presented in the table which follows.

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*Excluded airports are generally characterized as having relatively few daily jet operations and minimal to no adverse population noise exposure.

Study Rports

Rpot Category	Number of Airports in Category	Selected Rports
A	13	Miami, FL (MIA)
B	1	La Guardia, NY (LGA)
C	44	San Antonio, TX (SAT)
D	71	Sioux Falls, SD (FSD)
Total	129	

Much of the analysis in this report of noise abatement and control options use the forecast experience of the four Rports as a basis and is further predicated on generalized distribution of runway operations and flight tracks. However, calculations are also made for 10 airports to determine the noise implications of preferential runways and curved flight tracks. The procedure employed to generate a comparison of a base case assuming even distribution of runway and straight flight tracks with a system of priority runways and curved flight tracks, also is presented in Chapter III.

PROGRAM SCENARIO DEVELOPMENT

Chapter IV of this study describes the procedures to develop the scenarios from which program impacts and issues are assessed. Principal elements of the procedures involve air carrier fleet forecasts, demographic forecasts, representative airport program costing, alternative flight procedures, optimized ground tracks and controls on residential encroachment.

Fleet Forecasts

Since the projected mix and number of aircraft operations will have a direct bearing on the level of airport community noise exposure, the fleet mix was developed for base year 1979 and for forecast years 1990 and 2000. Aircraft growth was based on a moderate 1.7 percent annual growth rate in total aircraft. However, reference to the number of aircraft understates the expected rapid expansion in commercial air service. As new aircraft types are introduced into fleet service, they will replace older types which not only are noisier and less fuel efficient, but also have lower seat capacities. As shown in the table below, between 1979 and 2000 the number of commercial aircraft is estimated to increase 42 percent and the average seats per aircraft to increase 104 percent. The larger capacity aircraft require many fewer annual departures to handle any given passenger demand level, thus explaining the decrease in departures in year 2000.* However, the larger aircraft will be noisier than smaller aircraft using the same technology.

Air Carrier Fleet Forecasts

	Baseline	Forecast Year.	
	1979	1990	2000
Number of Aircraft	2,384	2,870	3,397
Average No. of Seats per Aircraft	156	231	319
Number of Departures in Thousands	4,606	4,777	4,394

Noise Source Regulation

Noise levels for existing and new production aircraft are governed by Federal Aviation Administration Regulations (FAR 36). Compliance depends upon when the aircraft are designed and produced, with the existing noise limits designated as Stage 1, 2 or 3. The changing mix of aircraft will evolve toward meeting the Stage 3 level. For example, 21 percent of the air carrier fleet met Stage 2 at the beginning of 1977 and 48 percent at the beginning of 1981. About 86 percent of the U.S. fleet is expected to meet Stage 2 by 1985.

The airport-community noise benefits of the more advanced control requirements for Stage 3 aircraft will not accrue for some time due to the 20 year or so lead time required for new noise technology aircraft to make up enough of the air carrier fleet to make a noticeable impact on community noise exposure. Thus, the generation of aircraft using the Stage

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*Total seat capacity increases from 372,000 to 1979 to 1,082,000 in year 2000, a 191 percent increase over the 21 year period.

3 technology developed in the late 1970's will not begin to fully impact exposed communities until the late 1990's.

Demographic Forecasts

Housing, population and other demographic patterns around airport communities have not remained static in the past, nor are they expected to remain so in the future. For example, many communities (defined by noise contour bands) experienced different growth rates for population and residential units during the 1970's. These and other changes are captured by updating selected demographic variables based primarily on growth rates for population and households. Exposure parameters selected for detailed analysis in this technical supplement are: (1) population; (2) area; (3) residences; and (4) program cost.

Representative Airport Program Costing

Estimates of the four previously mentioned exposure parameters were developed from data for selected noise contour bands. Estimates a population, area and residences were obtained from computer program outputs described in Chapters III and IV. Representative airport program costing was performed by multiplying the average cost of soundproofing or relocating a residential unit by the number of those units in a given noise contour band.

Noise Abatement Flight Procedures

Aircraft are capable of using a variety of safe departure procedures, each of which generates different noise levels and different airport-environs noise exposure patterns. The three take-off procedures assessed in this study are:

- AC 92-39 (recommended by the FAA in Advisory Circular 91-39)
- ALPA/NWA Max (recommended by the Airline Pilots Association, or ALPA)
- ALPA/NWA Min (also recommended by the ALPA).

SCENARIO DESCRIPTION AND PROGRAM IMPACT

An airport proprietor has available a number of options and perspectives from which to address the airport-community noise exposure problem. These are assessed in Chapter V by means of scenarios which are developed by varying the factors which strongly influence the extent of airport noise exposure. A measure of the effectiveness of noise abatement options is gained through a comparison of exposure levels associated with various fleet forecast years.

Land Use Control

A major problem faced by many air carrier airports is the encroachment of non-compatible residential development into areas adversely impacted by airport noise. Benefits which might otherwise accrue from noise abatement actions often are more than offset by population or residential growth. The table below summarizes the benefits of aggressive noise compatibility planning and implementation on noise exposure levels associated with the year 2000 air carrier operations.

	Year 2000 Population (in thousands) by L_{dn} dB Contour		
Land Use Control Implications	65 to 75	75+	Total
Unrestricted Population Growth	3,489	139	3,629
No Growth After 1990	2,766	119	2,885
No Growth After 1979	2,185	101	2,287

A measure of the opportunity lost by not instituting effective land use control is that absent such control, normal population growth between years 1979 and 2000 would expose an additional 1.4 million people to adverse noise levels. The exposure numbers presented here and elsewhere in Chapter V are derived from a data base (see Chapter III) which does not consider actual airport runways and flight tracks. Accordingly, while presentation of actual values tends to provide a point of reference to quantify the airport noise problem, more importance is the relative change in these values as various noise control options are considered. For example, land use control in years 1979 and 1990 would reduce population exposure by 63 and 79 percent, respectively.

Alternative Flight Procedures

Unlike the abatement measures summarized earlier, use of alternative flight procedures does not offer the opportunity for generally uniform improvements in airport-environs noise levels. Rather, they tend to shift the locus and intensity of impacts between areas. For example, when considering the current fleet mix, the ALPA/NWA procedures may reduce total noise exposure as measured by people exposed to levels greater than L_{dn} 65 dB but they also increase exposure levels in areas closer to the airport already experiencing the most intense impact. The converse is the case for the AC 91-39 takeoff procedures. By the year 2000 with higher by-pass ratio engines the later procedure reduces exposure levels in absolute as well as relative terms, as shown in the table below.

An airline working with the airport proprietor might consider employing the ALPA/NWA Min or Max procedure for low bypass ratio engined aircraft and the AC 92-39 procedure for aircraft with high bypass ratio engines.

Priority Runways and Curved Flight Tracks

The baseline computer runs employed for this report were made using an equal distribution of operations on all runways suitable for these operations. However, special studies have been made to estimate the reduction in number of people impacted by aircraft noise and of cost of soundproofing and relocation when aircraft use runways and ground tracks which route them over the most sparsely populated areas. The priority rating of runways and ground tracks is based on population within the L_{dn} 65 dB contour. The first priority runway is used at all times when the wind limits permit, i.e., all head winds and up to 5 knots tail winds and up to 15 knots cross winds. The second takes what it can of that remaining time with the same limits. Turns are made in flight to avoid populated areas at FAA limited bank angles when the aircraft has achieved the FAA prescribed altitude and airspeed.

In general, significant reductions in noise impact can be made most airports using these procedures. This report presents data for (1) straight in and out ground tracks and equal distributions of operations on appropriate runways and (2) priority runways and curved ground tracks.

It was not possible within the scope of this study to obtain the actual runway distributions of operations and the actual ground tracks used at each airport studies. Thus, the benefits shown are from an arbitrary baseline to an optimum operating procedure.

A comparison of the effect of alternative airport procedures is provided below:

	Population Exposed to Greater than L_{dn} 65 dB (1,000's)	
Fleet Year	Straight	Curved
1979	7,553	3,014
1990	4,376	1,756
2000	2,287	834

The above estimates are on based on the forecast experience of the four Rports. To forecast experience of an enlarged group of 10 airports indicates a potential population noise exposure of 50 percent when considering straight flight tracks and even runway distribution with curved flight tracks and priority runways.

Expanded Soundproofing Zone

. It is recognized that the pattern for the development of compatibility in a practical manner may differ from one airport to the next. The noise exposure level (L_{dn}) at which the strategy for developing compatibility shifts from soundproofing to relocation, for example, may be moved upward for apartment houses, or houses with essentially no outside grounds with gardens and play or living space, as compared with houses with such outdoor amenities. Thus, in some areas with essentially no indoor living, people can be protected from outdoor L_{dn} levels of 80 or higher if their residences are soundproofed to indoor levels of L_{dn} 45 dB or lower.

There is also the practical problem of overall cost for the development of compatibility. If the area from which residents are being removed is to be converted to industrial or some other compatible use, there is the question of the amoutn of land vacated per dollar cost to the project. The land area vacated by apartment dwellers or dense housing areas is small compared with single family houses with lawns, gardens, etc. For this reason and because the per unit cost of soundproofing of apartment is less than for single family houses, the cost of relocating familiers from apartments compared with soundproofing is much higher than for single-family houses with grounds.

There is also the important question of the desires of the people living in high noise exposure areas. In some cases, segments of the exposed population are seriously disturbed by the noise but initially don't want to relocate. However, after their neighbors have moved they don't want to stay in a partially deserted area. The development of practical plans to meet the needs of each local situation must be made at the local level with all elements of the local situation involved in the planning. For the above reasons the costs for soundproofing and relocation have been determined for:

- Class A -- Soundproofing increases of L_{dn} 65 to 75 dB and removal in areas above L_{dn} 75 dB
- Case B -- Soundproofing in areas of L_{dn} 65 to 80 dB and removal in areas above L_{dn} 80 dB.

The costs are developed for both A and B recognizing that at some airports (such as LaGuardia) the soundproofing may be used even above L_{dn} 80 dB and at other airports there may be no soundproofing above 75 L_{dn}. Of course, by the year 2000 there will be many airports in the categories studied where there will be no areas above L_{dn} 75 dB.

RELOCATION COSTING PROCEDURES

Chapter VI describes the framework from which the relocation costs were developed. The type of assistance which may be offered in a given relocation/soundproofing program is modeled after the requirements of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of

1970. The framework begins with an overview of the applicability and requirements of this Act. Next a set of relocation cases is defined and a procedure to estimate the frequency of each case is set forth. Finally, costs associated with each program element covered by the cases are presented.

II. SOUNDPROOFING/RELOCATION PROGRAM
ISSUE ANALYSIS

The airport soundproofing/relocation program discussed in this study is proposed to complete the achievement of compatibility after all practical airport noise abatement actions have been taken under FAA's Part 150 (Reference 1). Affected residents are defined in this chapter as those living in the areas which will be exposed to airport noise levels in excess of L_{dn} 65 dB in the year 2000. (See Chapter V for quantification of affected population and measures which can minimize airport-community noise exposure.)

The carrying out of this objective implies that fairly detailed plans must be developed specific to each airport. However, before such detailed planning can commence, it is necessary to consider a number of issues which may have a substantial impact on the content of the plan finally produced and on the probability of its successful implementation.

Some of the issues that could be raised by the attempt to plan and implement a soundproofing/relocation program are discussed in this chapter. The list is fairly complete, since if an issue is not raised, it may prove to be an unexpected impediment to program implementation at a later date. The discussion of each issue of necessity is general, since specific airports are not considered at this time.

It is not sufficient simply to raise issues, but to suggest alternative means for resolving the issues. The means selected will be an element of the plan for a particular airport. Means for the resolution of issues must be equitable for all parties involved. They must also be politically, economically and socially realistic.

FRAME OF REFERENCE

It is necessary to consider the general framework within which the program will be conducted. Once the issues associated with the establishment of this framework have been brought to light, a great many subsidiary issues will become apparent. Therefore the initial set of issues are those dealing with specific program objectives, the principal protagonists in program planning and implementation, the legal framework within which they must act and the relationship of the goals of the program to the goals of the airport and the community in general.

Having established this general framework, it was possible to proceed to subsidiary issues in succeeding sections.

Specific Objectives of the Program

The Federal government has undertaken a series of steps to provide relief to residents in the vicinity of airports who are subjected to excessive noise. In promulgating Part 150, the FAA has taken an important step in this direction by providing standardized procedures for individual airports to develop a plan for noise alleviation. This Federal effort has been amplified to include a program for residential soundproofing in sound-impacted areas or relocation of residents where soundproofing is not feasible. This soundproofing/relocation study is a step toward achieving the general objective of providing noise relief to affected residents.

This general objective must be translated into a series of specific objectives that will guide implementation by an airport of the soundproofing/relocation program. These specific objectives must recognize the legitimate needs and responsibilities of the various parties concerned with an airport's operation and development. Implementation of the program will be expedited, as pointed out in the FAA Advisory Circular entitled Airport Land Use Compatibility Planning (Reference 2), if all such parties (see Table 2.1) are involved in its planning. To determine how these parties can contribute to the planning process, it is useful to examine their specific objectives. The essential element of the planning process then is the integration and reconciliation of the frequently conflicting objectives of the individual parties.

In all cases, an interested party is assumed to have the particular objective of minimizing his contribution to the cost of the program. Thus, the objectives discussed below exist in addition to the cost minimization objective. Cost as an issue is discussed in a following section.

The airport proprietor (i.e. a city, county, authority, board, etc.), as operator and owner, provides air service to the community at a profit, or within a specific budget. The proprieter will be primarily responsible for planning and implementing the program, with the assistance of various agencies and governmental bodies. Exercise of this responsibility must be within an established legal framework with respect to noise. Generally, the proprietor has the power to select an airport site, acquire land, promote compatible land use, and control airport design, scheduling and operations. Limitations on this power are subject to constitutional prohibitions against the creation of an undue burden on interstate and foreign commerce, unjust discrimination and interference with activities pre-empted by the Federal government (i.e., FAA responsibility over safety and airspace management). This pivotal role of the airport proprietor derives in part from the mentioned responsibility. Perhaps equally important, however, is the fact that the proprietor is closest to the noise problem, with the best understanding of both local conditions, needs and desires, and the requirements of air carriers and others that use the airport.

TABLE 2.1
PARTIES INVOLVED IN PLANNING/IMPLEMENTING A SOUNDPROOFING/RELOCATION PROGRAM

1. Airport Proprietor
2. Federal Aviation Administration
    - General National Aviation System Responsibilities (e.g., development activities, funding source)
3. Airport Users
    - Customers
        - Traveling Public (business and leisure)
        - Cargo Shippers
    - Aircraft Operators
        - Air Carrier Airlines
        - Cargo Carriers
        - Military
        - General Aviation
    - Airline Pilots
4. Airport Communities
    - Private Sector (business)
    - Affected Residents
    - Non-Affected Residents
5. Governmental Bodies
    - Municipal (local)
    - County
    - State
    - Regional
6. Other Airports (competitors)

The specific objectives of the proprietor in undertaking a soundproofing/relocation program are:

- To avoid noise damage claims
- To provide space and climate conducive to airport expansion
- To avoid curfews and capacity limitations.

The first objective is probably the most significant from his viewpoint. Courts have held that noise impacted homeowners can legally collect for damages (and collect again after a stated period). Perhaps just as important, the program is envisioned as a major tool which, when used in conjunction with other noise abatement options, would improve the image of the airport in the community. This in turn would help reduce community objections to airport expansion activities whether they involved physical expansion of runways or actions enabling an expanded number of aircraft departures. Obtaining space for expansion can be used as a rationale for undertaking the program. Expansion is needed to allow airport traffic to grow with the community. Finally, the imposition of curfews and similar measures obviously would lessen the airport's income and provision of service and thus is to be avoided if possible.

The FAA in its role of providing air traffic control and management of navigable airspace has the objectives of insuring the expeditious flow of traffic, and insuring the safety of passengers and persons on the ground. The basic national policies intended to guide FAA include:

- Regulation of air commerce in a manner to best promote its development and safety

- Promotion, encouragement and development of civil aeronautics

- Control of navigable airspace and the regulation of both civil and military operations therein in the interest of safety and efficiency

- Development and operation of a common system of air traffic control and navigation.

Aside from operational changes to reduce noise, a soundproofing/ relocation program as such may have an impact on the traffic control function of FAA by improving take-off and landing safety. This improved safety results from the removing of residences from under the landing approach path. As monitors of Airport Development Aid Program (ADAP) funds, FAA has the objective of dispensing these funds where they contribute the most to the development of the National Aviation System. The FAA also provides financial and technical assistance to airport proprietors for noise reduction planning and abatement activities, consistent with the highest standards of safety.

The airport's customers (i.e., the traveling public and cargo shippers) have an interest in airport noise control as it may affect the service offered. One suspects the average passenger almost never thinks of the noise his travel may impose on persons on the ground. Airport users (i.e., air carrier airlines, cargo carriers, etc.), however, are most certainly aware of the noise problem. Their objective is to continue to operate at their current level, or to increase their level of operations. Recognizing that a severe noise problem may curtail their operations, they may support a soundproofing/relocation program. In fact, a program may be more acceptable than alternatives such as curfews and capacity limitations. Both customers and users would have a heightened interest in the program if required to fund the effort in whole or in part. Realization of the economic impact would depend on the funding level and mechanism employed as well as the relative allocation among the groups. For example, landing fees would directly impact the airlines, who could pass all or portions of the costs to customers in terms of higher ticket and air cargo rates. Interest among customers would not be as great here as under a funding mechanism calling for specific noise charges as a line item on each ticket or tariff.

The objective of airline pilots is to approach, land, take-off and climb-out with the minimum difficulty and in the safest manner. Special flight procedures are felt by some to hinder attainment of these objectives. Hence, if a choice had to be made, airline pilots may prefer a soundproofing/ relocation program over special flight procedures. It is recognized that the FAA has ulitmate authority over safety; alternative flight procedures which adversely affect air safety would not be allowed. However, the opinions of airline pilots are well integrated into the FAA decision-making process and their cooperation or even encouragement would no doubt increase a proposed program's acceptability.

When discussing the objectives of airport communities, it is necessary to distinguish residents and businesses as a group and local governmental bodies as another group. Businesses, or the private sector in general, as represented by Chambers of Commerce or similar groups, are almost always in favor of high levels of operations at the local airport, and also in favor of physical expansion when there is a need to increase this level. They feel that good air service is good for local business. They tend to oppose curfews, capacity limitations and similar measures. To gain land for expansion and to eliminate the need for curfews, etc. they probably would favor a program if necessary.

Residents in affected areas logically might be expected to be in favor of a soundproofing/relocation program. However, experience with voluntary relocation programs has shown that only limited acceptance of relocation offers can be expected. Relocation thus becomes a desirable option when it is someone else's home or neighborhood to be affected. Strong neighborhood ties are the apparent cause of this reluctance. Hence the objective of many affected residents is to "stay put". Note that opposition from residents in non-affected areas can be expected if they are asked to pay part of the program's cost through increased taxes.

At the municipal or county government level, a large number of possible objectives can be listed. These can be discussed roughly in order of activity required. At the lowest level, the objective could be to maintain neighborhood integrity. Massive relocation could, in effect, destroy a neighborhood with a strong religious or ethnic component. This would lead to opposition to carrying out the relocation part of the program (but perhaps not the soundproofing part). Relocation also could possibly disrupt the carefully balanced local political structure that may exist in some cities. In these cases, the objective of the local government might be to oppose the relocation part of the program. Relocation, and its attendent erosion of local tax bases, would certainly meet with strong governmental opposition.

In some cases, there may be a few residences in a noise impacted region that are scattered among industries or other buildings. Since these industrial land uses are probably noise compatible, a relocation program would involve only removing the isolated residential structures. Thus, if the objective is to make the area noise compatible, the relocation effort involved would be minimal.

Aside from these somewhat minimum effort programs, a local government may have objectives that require complete clearance of the impacted area. Such objectives might be:

- To obtain land for public facilities such as parks, sewage treatment plants, water resevoirs, etc.
- To provide land for airport expansion
- To redevelop the area for a higher use to increase the tax base
- To eliminate a blighted area to reduce crime and the cost of public services.

These objectives are not mutually exclusive. Further, whether acquired land can be adapted to so-called higher uses remains questionable, particularly if it is to be accomplished on a major scale.

The described objectives of the local government reflect the broad responsibilities over the "body politic". However, an action that might favor the community at large may lead to resistance from specific individuals or businesses. Furthermore, residents in a high noise impact area are often extremely vocal in expressing their annoyance to community leaders, but at the same time (as mentioned) may just as vehemently oppose relocation. A careful balancing of individual versus community-wide interests is thus necessary.

The objective of state governments in undertaking a program in some cases are similar to those of local governments. In addition, certain unique objectives apply at the state level. The similar objectives include:

- To provide better air service
- To avoid curfews, etc.
- To obtain land for public facilities
- To provide for airport expansion
- To redevelop the area
- To eliminate a blighted area.

The unique objectives applicable to the state case are:

- To undertake programs that local governments will not undertake for social or political reasons
- To assure a better financial base for the program
- To ease the local tax burden.

The first of these recognizes that a state government can overcome local opposition to a program stalled by local government objections of the type mentioned above. The second and third recognize that the financial resources of the state are greater than those of local governments.

A regional group of states may undertake a program with the objective of accomplishing a needed program where the impacted area lies in more than one state (e.g., Cincinnati, Philadelphia, Omaha). Also, such a grouping may be desirable to assure that fees or taxes in one state to pay for the program do not divert traffic to an airport in a neighboring state.

As with any major new program, initial opposition may in large measure be based on fears which later prove to be unfounded. The relative costs and benefits, on an individual and collective basis, may not be readily apparent. Effective planning and early and open community involvement is thus considered a necessary program element.

Role of Noise Measurement

Applicability of, and eligibility for, a relocation/soundproofing program is most reasonably determined on the basis of noise exposure levels. Consequently, the definition of contours of constant noise exposure has great importance. The primary tool for this process is the use of airport noise prediction programs. The accuracy of noise exposure calculation procedures is, therefore, of concern.

Assuming that contour lines are precisely and accurately determined, using procedures specified in the FAA regulation Part 150, the larger question -- as to how this information is to be applied -- should be considered. The precise contour lines can not be implemented as rigorous boundaries for program action since they would split communities, neighborhoods, blocks and even individual structures and dwellings. Thus, the contours would have to be flexibly applied with a considerable degree of judgement. This judgement must be primarily based upon land use planning and economic and political considerations. Consequently, the technical benefits derived from measurements are unnecessary since approximations provided by computer prediction programs are a sufficient basis for program decision-making. These considerations are addressed below.

SOUNDPROOFING CONSIDERATIONS

There are a number of issues specifically related to the soundproofing component of the program. In general these issues can be classified as technical and programmatic. Technical issues involve standards, specifications, quality control, ventilation and similar items. Programmatic issues involve mainly legal and cost questions. Obtaining a waiver of damage liability in exchange for soundproofing is an example of a legal issue. The question of cost sharing by residents is an example of a cost issue.

Installation Specifications

The specific building modifications required to achieve an acceptable interior noise level (defined as L_{dn} 45 dB) are strongly influenced by the construction characteristics of the dwelling and its state of repair. The construction patterns vary considerably among geographic regions, but are fairly uniform within a region. Chapter IV of this report describes eleven regions with fairly homogeneous construction patterns and presents average costs of soundproofing average dwelling units within each region. Although soundproofing modifications will vary, they can generally be grouped by outdoor noise level as follows:

- L_{dn} 65 to 70 dB -- sealing leaks and improving weatherstripping
- L_{dn} 70 to 75 dB -- as above, plus installation of storm windows, storm doors and roof insulation (where necessary)
- L_{dn} 75 to 80 dB -- as above, plus modifying walls to add insulation (where necessary).

The application of these controls will vary with individual rooms depending upon room features (number and types of doors) as well as the building construction (type of exterior walls and roof) and condition (presence and condition of weatherstripping) such that room noise reductions of 0-5 dB, 5-10 dB and 10-15 dB, respectively for the exposure ranges mentioned above, will be required.

A catalogue of specific noise control modifications can be developed which defines the required features to achieve the desired interior noise levels as a function of the exterior noise level and building element type and its construction and condition. These modifications could be selected when a given noise path is determined to require increased attenuation. Contractor hiring and cost estimation can be performed after identifying the numbers of each specific modification required to soundproof some given number of buildings.

A special problem could occur when the dwelling is fairly rundown. Here there are likely to be many cracks and gaps (some quite large) which provide leakage paths for exterior noise. An extensive degree of refurbishment would be needed to achieve the desired sound attenuation. Furthermore, the dwelling is likely to have numerous building code violations which would have to be corrected before a construction permit is granted. All of these factors add substantially to soundproofing costs, which may in certain instances be prohibitively expensive. In such cases, consideration might be given to relocating the affected residents as an option to soundproofing. A blighted neighborhood would contain many such dwellings and piecemeal relocation would generate problems, discussed elsewhere, associated with a checkerboard housing pattern. A further option would thus be the wholesale relocation of the blighted neighborhood.

Provision For Variations

Considerable variations are likely to exist from dwelling to dwelling with respect to not only construction features and structural condition but also the presence of owner modifications such as enclosed porches and large dormers. Three general approaches exist which can be used in specifying the soundproofing modifications:

- Uniform installation of treatments regardless of dwelling-specific characteristics
- Installation of treatments based upon visual inspection of each dwelling
- Installation of treatments based upon acoustical testing of each dwelling (with or without retesting after installation).

The first approach described would be the simplest to implement. However, some dwellings may be given unnecessary noise controls and others insufficient features. The last approach conforms to the more standard noise control engineering practice of identifying and quantifying noise paths. It defines precisely the features which will be required for each dwelling. However, this approach has the disadvantage of considerable testing cost. The second approach is perhaps a compromise between the others. It provides some degree of "tuning" of the features to each structure with moderate program cost for inspection. However, this approach would not be sensitive to the isolation of small sound leaks which could substantially nullify the benefits of high noise reduction installations. Visual inspection — perhaps in conjunction with some sort of post-modification performance verification — is probably the most cost-effective procedure. (See discussion below on soundproofing performance verification.)

Another type of variance could arise when the homeowner or landlord wants to take advantage of a proposed soundproofing effort to install special features to enhance the enjoyment of the unit and increase its value. If walls are to be modified, for example, upgraded electrical wiring or special wall finishes may be desirable. Another example would be upgraded duct work as a predicate for installation of a central air conditioning system.

Consideration of owner-suggested variances could increase program costs, especially if it prevented adoption of the uniform installation technique. On the other hand, it would help encourage voluntary or even active program participation.

Ventilation and Air Conditioning Options

The exchange of air inside buildings with fresh outside air is a natural and necessary process. It is necessary in order to rid buildings of air with a high density of carbon dioxide and to clear the air of contaminates (such as smoke from cigarettes, cooking and heating by-products and dust). Current residential buildings in the U.S. typically have air infiltration rates of one to two air changes per hour. The minimum specified by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) is one air change per hour - with greater exchange rates in areas of heavy smoking.

From an enery conservation point of view, reduced air infiltration rates are desirable. Homes have been built with rates as low as 1/4 air change per hour although at low infiltration rates problems of aesthetics and health become significant. The problems include increased odors from human activities, increased humidity and increased chemical and radiation contamination, such as formaldehyde and radon gas emitted from the building materials (particularly, masonary products). The radon gas, RN 222, is a decay product released naturally by trace amounts of uranium in rock and soil. The amount that accumulates indoors is minimized as air is rapidly interchanged with fresh outdoors air. Radon-rich air in uranium mines is known to cause lung cancer and is considered by some to be a potentially significant hazard in energy efficient homes (Reference 3). In the context of the sound-proofing program, provision of ventilation would be required although the absolute quantity of ventilation should be the minimum necessary for comfort, aesthetics and health.

The most effective way to ventilate soundproofed homes is by means of a central forced-air system. The use of central air ventilation can be readily adapted to central air conditioning. The cost for the addition of air conditioning in soundproofed dwellings has been estimated as $400 to $2600 for single family buildings and approximately $400 per residence for multiple family structures (Reference 4). Where central air conditioning does not already exist in a structure to be soundproofed, its installation could be at the building owner's option and cost. The use of central air conditioning does have the benefit of eliminating the need for acoustically baffling any existing window or wall mounted air conditioner units. In these cases credits could be provided building owners for any savings obtained from not baffling room air conditioner units.

Soundproofing Performance Verification

After soundproofing treatments have been installed, verification measurements are desirable to evaluate the effectiveness of soundproofing modifications installed after only a visual inspection, to identify performance deficiencies resulting from incompetent or dishonest contracting, or to evaluate the adequacy of installed treatments where dwelling-specific features such as enclosed porches and large dormers exist. These performance verifications might take any of three forms:

- Indoor aircraft noise monitoring

- Exterior building wall noise reduction measurement

- Acoustic leak location.

Interior noise monitoring has the benefit of evaluating the actual performance of the structure in obtaining the desired performance goal. However, its implementation includes many of the difficulties involved in outdoor noise monitoring, such as those related to sampling (see previous discussion on the role of noise measurement). Indoor measurement presents additional difficulties related to the selection of appropriate measurement locations within the dwelling and the effects of background noise generated within the dwelling (which could often exceed that due to exterior noise sources). Furthermore, indoor monitoring would intrude upon the occupants of occupied dwellings although this may be minimized by measuring a very limited sample. (This limited sample might consist of perhaps 10-15 flyovers, preferably of noisier aircraft types, recorded as single event, sound exposure levels.)

The evaluation of building wall noise reduction performance involves the measurement of sound levels both inside and outside the building structure. It eliminates the difficulties related to sampling and background noise which exist for monitoring. However, existing and draft measurement procedures developed by the International Standard Organization (ISO) and the American Society for Testing and Material (ASTM) are not widely used and have poor repeatability. Significant problems related to their implementation arise from the variable effects of sound absorption in the interior rooms as well as the location of interior room measurement positions. Additional practical problems involve the locating of test noise sources (primarily loudspeakers) and exterior microphones -- particularly with respect to high-rise structures. Actual aircraft flyovers could be used as the source of noise but measurement errors would be caused by uncertaintities in the exterior noise measurement and variability of aircraft flight tracks. The aircraft flyover approach has been implemented in a well controlled situation with good correlation with the loudspeaker noise source measurements (Reference 5).

Leak detection has the advantage of simplicity of both procedure and required equipment and has even been proposed as a means of detecting air infiltration openings in buildings for energy conservation. Equipment required for such a verification method would involve simple noise sources such as an inexpensive loud speaker and cassette recorder, and elementary sound detecting devices such as a plastic headset of the kind provided to airline passengers. This method would be unaffected by many of the drawbacks of the above procedures but does not provide a quantitative evaluation of structural performance and is not suitable for evaluating performance deficiencies of large distributed surfaces such as windows.

All performance verification methods discussed above have inherent disadvantages. Consequently, the requirement for a post-modification verification is best met by the use of visual inspections as a primary quality control technique. Where deficiencies are suspected but not visually determinable, limited interior noise monitoring and/or leak detection techniques are most suitable.

Noise Liability Waiver

One goal of the soundproofing program is to improve the welfare of the affected population. Another goal is to protect the airport against the threat of adverse noise suits. To better understand the implications of airport noise litigation, it is useful to briefly relate the general theories under which noise damages have been assessed.

Noise Liability Theories. The first, and most traditionally applied, theory is inverse condemnation which is broadly defined as the deprivation of private property by a party or agency without just compensation. The basis for the theory is that a property owner suffers a diminution in the market value of the property as a direct result of airport noise which causes a substantial interference with the use and enjoyment of the property. Loss of use and enjoyment of land would constitute a taking of property and, absent compensation, would violate the fifth amendment of the Constitution. Application of this general theory varies significantly among jurisdictions. Whether a particular party would be able to sustain the burden of proof of showing that airport noise was the proximate cause of reduced property values would depend on the facts involved. The same holds true for the amount of damages which might be awarded. It is important to note, however, that such awards generally would be lump-sum payments and apply exclusively to property damages.

Damages under the nuisance theory, however, may entail continuing liability on the part of the airport proprietor. Generally defined, nuisance is that which annoys or disturbs one in possession of his property, rendering its ordinary use or occupation physically uncomfortable to him. Nuisance cases arise as a matter of "equity" wherein the courts balance the interests involved. This allows distinguishing between disturbances which are inconsequential, those that are offensive only to hypersensitive individuals and those that affect ordinary comfort as defined by the customs of a community. Thus, a nuisance may exist even in situations where some people are hardened to the discomfort but a normal person would still be adversely affected. Furthermore, nuisance need not arise out of a negligent act or conduct. Sometimes an activity is a nuisance per se, without regard to the care with which it is conducted or the circumstances under which it exists.

Upon a finding of a nuisance, the courts may grant a single award for past and prospective damages, or entertain successive actions for a continuing nuisance. A case in point is Greater Westchester Homeowners v. City of Los Angeles, 8 ERC 1406 (Cal. Super. Ct. 1975), aff'd, Greater Westchester Homeowners Association v. City of Los Angeles, 14 ERC 1074 (Cal. Sup. Ct. 1979). The lower court noted that the decisional law "...indicates that a loss to the homeowners of the use and enjoyment of his home which results in his annoyance, discomfort, mental or emotional distress is a compensable injury insofar as ...nuisance is concerned". Specifically rejected by the court was the arguement that affected residents assumed the risk of noise by moving into the area after the institution of jet operations at the airport. Accordingly, 41 plaintiffs were awarded damages in the aggregate sum of $86,000 plus attorney fees.* Since airport noise was expected to continue to be a nuisance, the court further noted that "the awards to those plaintiffs will not constitute a bar to future claims by these plaintiffs against the defendent city for the continuing emotional and mental distress caused by the continuing nuisance of noise from jet aircraft."

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*The plaintiffs also brought suit for property damages under the theory of inverse condemnation, award for which was not the subject of the referenced litigation.

The court went on to note several alternatives which the city might consider in relieving itself from continuing nuisance liability. These are:

- Reduction in the jet aircraft decibel level
- Acquisition of homes through voluntary agreements or through direct condemnation actions
- Soundproofing of residential properties.

Although not binding on the disposition of the case, the court "unequivocally and unhestitantly" suggested that homeowners ought not to be forced to live in a situation of being subjected to jet aircraft noise nuisance and then periodically suing the city of Los Angeles for damages.

Liability Waiver. Given the distinction between inverse condemnation (lump-sum, property damage) and nuisance (continuing, personal injury damages), the utility of a liability waiver may be addressed under each theory seriatum.

The measure of damage of inverse condemnation is the reduction in property values attributable to airport noise. A general measure is provided by Nelson (Reference 6) whose studies suggested a noise discount of about 0.5 percent per decibel. A home in a L_{dn} 65 to 70 dB contour would thus experience a 2.5 percent reduction in property value.* Similarly, the reduction would be 5.0 and 7.5 percent for homes in the L_{dn} 70 to 75 and 75 to 80 dB contours, respectively. Assuming an average home value of $40,000, this is a property value reduction (and therefore potential liability) of $1,000 to $3,000. These values compare favorably with the cost of soundproofing most homes in most soundproofing regions. It could thus forcefully be argued that acceptance of soundproofing assistance would substantially militate liability as home values would appreciate by an amount closely offsetting any depreciation attributable to excess airport noise.

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*Assumes a comparison of a dwelling situated in the mid-range of a L_{dn} 65 to 70 dB contour as compared to the mid-range of a L_{dn} 60 to 65 dB contour which would be outside the soundproofing zone. This measure excludes any appreciation in property values associated with the desirability of proximity to the airport proper - often a major employment center (see Chapter VI discussion of relocation replacement cost).

Notwithstanding this point, a waiver would still be desirable since it would (1) preclude with greater certainty damage assessments and (2) obviate the need for often expensive attorneys fees associated with defending inverse condemnation suits.

In the case of nuisance, there is no systemmatic measure of potential liability because of the more speculative nature of personal injury damages. Impacts such as interference with person-to-person communication, ability to enjoy the use of the out-of-doors portion of property, sleep and the enjoyment of television are difficult to quantify and are extremely dependent upon localized conditions. Adjustments to property values related to soundproofing improvements would not obviate potential nuisance awards for past or future personal injury. Furthermore, while soundproofing would assure a quiet environment within a home, the use and enjoyment of the out-of-doors would remain impacted.

Liability waivers would thus be highly desirable, if not essential, as a pre-condition to offering soundproofing assistance.

Period of Acceptance

In some of the types of soundproofing efforts, the resident would have the option of accepting or rejecting an offer to soundproofing his residence. If he rejects the offer, he may or may not be required to give a noise easement to the implementing agency. In either case, a question is raised concerning the program's duration, or how long should the offer to soundproof remain open? This queston implies that a fixed acceptance period should be established beyond which the program is terminated.

In some soundproofing efforts, the resident may be required to accept the soundproofing offer, or if the offer is rejected, required to meet other conditions, such as assigning a noise easement to the agency. In these mandatory situations, the acceptance period can be limited to the time required to contract for soundproofing or the time required to complete legal and financial arrangements. In other soundproofing variations, the resident may have his home soundproofed if he chooses, or decline soundproofing with or without conditions. In these voluntary cases, the acceptance time would presumably be longer than in the previous cases, since it seems more compatible with the character of a voluntary program to give the resident more time to come to a decision.

However, from the point of view of the agency, an extended, or indefinite, acceptance period has two disadvantages. First, the longer the period, the longer the agency must maintain offices, counseling centers, staffs, etc. to support the program. This continuing expense is not justified after some initial period, since the rate of acceptance of offers will probably decrease greatly with time.

Long term financing of the program probably is easier to arrange if a good estimate of the number of acceptances can be obtained early in the program. A short acceptance period allows this to be done.

A program of soundproofing between the L_{dn} 65 to 75 dB contour is envisioned here as part of a larger program which includes relocation inside of the L_{dn} 75 dB contour. The best time periods for the relocation and soundproofing elements of the program may not coincide. Although some partial reduction in administrative staff, etc. can take place at an intermediate point in the program, some attempt to match the time periods is probably most efficient.

Cost Sharing

A comparison of average unit soundproofing costs and property value diminution related to airport-generated noise was presented earlier. (A more detailed presentation of soundproofing costs by structure type, outdoor sound level and geographic region is provided in Chapter IV.) Although comparing favorably with soundproofing costs in most instances, the diminution value is generally less. The argument thus could be made that the property owner would receive value in excess of potential damages and he should be required to contribute to the cost of soundproofing, perhaps equal to the cost differential.

However, such a stance considers only the inverse condemnation theory and not potential continuing liability associated with the nuisance theory. While quantification of damages under the latter theory are not possible in this study, it can be assumed that when added to inverse condemnation, total damage would at least equal or more probably exceed soundproofing costs. Since a liability waiver is considered an essential prerequisite for acceptance of a soundproofing offer, a cost sharing requirement might well thwart implementation of the program.

Two expections to this general proposition are extant. First, if the program is to accept or even actively encourage owner-specified variations which exceed nominal soundproofing requirements, a degree of cost sharing would be in order. The second exception relates to the desire to obtain maximum voluntary program participation. Here, a nominal cost sharing of 5 to 10 percent of total costs may help make the property owner feel he has a stake in improving the quality of life in his residence and in the general neighborhood. Nominal cost sharing could also be added only after a stated time to encourage early, voluntary program participation.

RELOCATION CONSIDERATIONS

There are a number of issues related specifically to relocation. These issues arise mainly from the specific objectives of the program. For example, if redevelopment is contemplated within some time period to obtain land for industrial purposes, then relocation would have to be mandatory in order to insure that the land involved would in fact be available for redevelopment. Achievement of some of the other specific objectives discussed previously only require voluntary relocation. Many relocation issues derive from this basic issue of whether relocation is mandatory or voluntary. An example is the availability of affordable housing for relocated residents. Other relocation specific issues are logical boundaries for the relocation area, maintenance of neighborhoods, etc.

Maintenance of Relocation Area

Special care must be taken by the relocation agency to prevent crime and vandalism in the relocation area. For any relocation effort, there would be a short or long period during which homes and rental properties are being purchased and demolished producing either complete or partial clearance of the area. Thus, during this interregnum, the area has a checkerboard pattern of structures and vacant lots. Unless certain steps are taken, this pattern may lead to undesirable effects on those residents who elect not to relocate.

The undersirable effects include occupation of vacant buildings by squatters, vandalism, arson, vermin, trash and, as a consequence of these, sharply reduced property values. Other consequences of a piece-meal decrease in the general population of the area might include a loss of neighborhood stores and possibly a drastic cutback of city services.

When buildings are purchased, but not immediately demolished, squatters almost invariably move in. Consequently, confrontations frequently take place when they must be evicted by the authorities. Squatters are a problem in any land clearance project; airport relocation programs would not be an exception. The problem initially appeared at Logan, and has appeared in France at Orly and Charles de Gaulle airports (Reference 7).

The obvious solution to the squatter problem is prompt demolition of acquired buildings. This means the agency must negotiate a demolition contract which provides for "on-call" wrecking services. Even if squatters do not move in, empty buildings are prime targets for vandalism and arson. These are dangerous to remaining residents, as well as to the local police and fire departments. Again prompt demolition is the solution.

In addition to actual building demolition, it is necessary to clear the area completely including foundations, and to eliminate possible nesting locations for vermin. Furthermore, in the Logan case, it has been found necessary to do something active with the vacant property in addition to the passive actions of demolition and clearance. If this is not done, vacant lots become trash depositories or parking lots for abandoned autos. Actions that can be taken include landscaping, use by neighbors for vegetable gardens and use as playgrounds. These actions have been part of the Logan Airport program in the Neptune Road area.

A problem for which there is no simple solution is the loss of neighborhood grocery stores, restaurants, dry cleaners, etc. Obviously, as the population in the area declines, such local businesses find it unprofitable to remain. This loss of neighborhood amenities is particularly hard on elderly residents, the ones likely not to relocate. Perhaps a local "shopping bus" to other business centers is a possible solution.

Another closely related problem without a simple solution is the closing of local churches and synogogues. A public sector solution probably is not possible.

Another problem is the possible loss of a neighborhood school because of decreasing enrollment. Here, an adjustment in school bus routes is obviously possible.

The seriousness of these last three problems is highly dependent on local conditions. For example, in the Logan-Neptune Road project, the area is effectively isolated from the remainder of East Boston by a rapid transit line and a freeway. This isolation made neighborhood stores, schools, etc. particularly valuable to the residents. In contrast, in the Seattle-Tacoma project (Reference 8), no such obvious physical boundary exists. Neighborhood facilities simply move slightly further away, but are still accessible. Also, the two areas probably differ in the basic character of their populations. That is, the Neptune Road population is probably more neighborhood oriented than the Seattle-Tacoma population, and thus more dependent on neighborhood facilities.

In summary, the relocation agency must be ready to undertake certain actions if the quality of life is to be maintained in the impacted area for those residents who chose to remain, or who have not yet relocated. Prompt demolition of acquired buildings and development for constructive neighborhood use of vacant lots are primary actions. In addition, the agency must be prepared to enhance (and pay for) city services such as police and fire protection, school transportation, trash collection, etc.

Relocation Boundaries

A certain amount of flexibility is required in setting the boundaries of a relocation area. Aside from the basic analytical and operational errors involved in determining the L_{dn} 75 + dB contour, there are a number of social and developmental reasons for considering some expansion or contraction of the region bounded by the nominal relocation contour.

There are also basic economic implications of a flexibile relocation boundary. Costs associated with the soundproofing/relocation program components are presented in Chapter IV. For the 1979 fleet year, average soundproofing unit costs are $1,920, compared to $33,370 per relocated residence.* A boundary which expands the nominal or primary relocation zone would substantially increase total program cost. A contracted or mixed relocation zone would of course offer substantial cost savings. A measure of the cost impacts of flexibile boundaries may be gained in reference to the Chapter V discussion of an expanded soundproofing zone. Note that this section assumes the relocation zone is defined by the L_{dn} 75 dB or greater noise contour; as an option, the zone might also be defined by the L_{dn} 80 dB or greater noise contour.

The non-economic reasons why it may be necessary to have flexibility in setting the boundaries for a relocation region include:

- The need to set the boundary of a relocation region at a well-defined physical feature

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*Costs are based on total residential units, which may range from a single unit home to individual units in an apartment building containing 50 or more rental units.

- The need to consider the social character of the regions on both sides of a boundary

- The need to provide land for industrial projects, civic projects or airport expansion

- The desire to eliminate blighted areas.

These four reasons are discussed in the following sections.

Well-Defined Features as Boundaries. The boundaries of a region should be established as closely as possible to major readily-identifiable physical features. Examples of such features are main streets, freeways, railroads and waterways. This would avoid situations such as occur under German relocation law, where boundaries can pass through houses. Since modifying the German law is difficult, such property owners may wait years to receive the noise compensation payments provided under the law. In Switzerland, by way of contrast, noise impact zones can follow roads, waterways, property lines and even forest edges or terrain features (Reference 9).

Land for Redevelopment. Achievement of the fundamental objective of providing noise alleviation for impacted residents does not necessarily require the area to be completely cleared. A number of mandatory and voluntary programs allow residents to remain under certain conditions. However, if the impacted area is to be redeveloped for civic, industrial or commercial use, complete clearance of residences is necessary. In such cases, noise alleviation is achieved although it may not have been the principal objective of the program.

Examples of redevelopment for civic purposes include use of the area for parks, water works, vehicle storage, etc. Examples of industrial and commercial uses include light to heavy manufacturing, warehousing and enclosed shopping centers. Included in this general redevelopment category could be the provisions of land for airport expansion. This does not refer only to runway extension. Land is also required for hangers, warehouses, freight depots, etc.

The amount of land required for any of the above redevelopment purposes may be considerably different from the amount included within the relocation zone. If it is significantly greater, then using noise alleviation as a rationale for the program is weak. This would then raise questions about funding, legality, etc.

In these redevelopments the area involved should be extended to a logical physical boundary (freeway, railroad, etc.). This will eliminate leaving a small housing area sandwiched between the redevelopment project and the boundary, for example, between a warehouse and a railroad.

Clearance of Blighted Areas. Another rationale for complete land clearance is the removal of a blighted area. Such an area frequently is characterized by deteriorating housing and commercial structures, high crime rates, vandalism, etc. The cost is high of maintaining police, fire and other services in such a region. This high cost and the undesirable social conditions lead to a desire to redevelop the area.

This type of situation has lead the city of Inglewood to undertake a redevelopment program (Reference 10). The area is under the approach to the main runway at Los Angeles International Airport. Since Hollywood Park racetrack is adjacent, the plan is to create an expanded, integrated amusement area. The remarks of the previous section concerning boundaries and amount of land needed are applicable also in this situation. However, the use of noise alleviation as a rationale for land clearance may be stronger in this case if it is reasonable to assume that the blight was caused at least in part by the excessive noise.

Nature of Relocation Assistance

Whether relocation of residents is to be provided on a voluntary or on a mandatory basis, the cost of such assistance would be substantial primarily because it would entail property purchases at fair market value. In addition, there is ancillary assistance that would be provided under most circumstances which would impose additional costs on a per unit and total program basis.

The actual mix of relocation assistance, and the attendant level of coverage, may vary depending on the particular circumstances and policies of implementing jurisdictions. However, an understanding of the nature of such assistance may be obtained through reference to the Uniform Relocation Assistance and Real Property Acquisition Act of 1970, 42 U.S.C. 4601. The provisions of the Act and circumstances in which it might apply are presented in Chapter VI. The types of assistance and cost reimbursement required are as follows:

- Advisory Service Costs. These are costs incurred by the agency implementing the relocation effort and cover activities such as appraisals, negotiations, relocation assistance and administration. They may also include the cost of locating and appraising comparable replacement housing units.

- Moving Costs. These cover reimbursement for reasonable moving expenses. All moves are treated as if they were local, with most implementing agencies interpreting this as a move not exceeding 50 miles.

- Purchase Price of Real Property. As tenants are relocated, rental unit owners are paid the fair market value for rental property purchases. Such properties may range from single unit structures to high rise apartments.

- Purchase Price of Owner-Occupied Units. Owners are paid the fair market value for property purchased.

- Replacement Cost. Relocated tenants and homeowners receive a payment to cover the increased rental or purchase price required to obtain comparable replacement housing in a quieter neighborhood.

- Increased Interest Cost. This cost item arises when the interest rate on a replacement mortgage exceeds the rate on an original mortgage. The current high mortgage rates would create a significant differential when compared to, for example, mortgages on homes purchased 5 or 10 years ago.

- Closing Costs. Incurred by all persons making a home purchase.

- Downpayment. This special provision in the Act is designed to assist displaced tenants in becoming homeowners. Cash allowances up to $4,000 are provided for downpayments.

- Income Foregone. This cost item compensates landlords for disruption of their business operations as they loose their existing tenants in the course of a relocation.

Although the level of benefits provided may vary, the assistance items described above would apply to the majority of relocation programs. Likely variations would occur in the provisions of downpayment assistance, which may not be provided as an added benefit to tenants desiring to become homeowners. Another example is an "incentive" payment, offered as an inducement to relocation. Emminent domain power could be exercised to force relocation. Even so, an incentive payment would be useful in minimizing protracted delays associated with condemnation suits.

Availability of Comparable Replacement Housing

The Uniform Relocation Act requires that adquate, affordable, comparable and socially acceptable replacement housing be available for persons displaced as a result of a relocation effort. While the relocation program addressed in this study is confined to the resolution of annoyance experienced by those who reside around airports, administrators of the program may face problems encountered by renewal projects in the past. Thus, the problems of adequate and affordable replacement housings for the relocation program is discussed in light of the parallel experience gained in urban renewal projects.

To minimize adverse effects of the relocation program upon displaced persons, a disequilibrium in the housing market around the airport should exist. To absorb initially displaced families there must be a sufficient rate of vacancy in housings which are affordable to middle and low income households. In the past such a condition was required to be certified by renewal projects before federally sponsored demolition could occur. Concurrently, a disequilibrium in high income rental housing should also exist. In this market, however, there should be a shortage, if new high income rental housing is to be rented at a favorable occupancy ratio (Reference 11). In fact, such disequilibria are rare and in recent years there have been indications that reverse disequilibria are more likely to occur. Namely, shortages of middle and low income housing and a surplus of high income rental units are becoming commonplace.

The notion of comparable, replacement housing implies that the structures in question could be compared in terms of a set of common attributes. And these attributes should reflect the characteristics of the units and their surrounding area such as:

- Ambient or outdoor noise level
- Accessibility to employment centers
- Socio-economic characteristics of neighborhood
- Characteristics and dimensions of the structure.

A pivotal objective of a soundproofing/relocation program is, as stated previously, to provide relief to residents exposed to airport-environs noise levels in excess of L_{dn} 65 dB. This does not necessarily rule out relocation to an area located within an L_{dn} to 65 dB contour. Such action should insure that the new residence has either already been soundproofed to achieve the desired indoor noise level or built initially to reach this level. In general, however, relocation should be geared to areas exposed to less than L_{dn} 65 dB so as to minimize impacting the enjoyment of the outdoors. This factor has added importance when considering a voluntary relocation effort; residents are more likely to participate if they are able to perceive maximum, tangible improvements in their everyday lives.

Accessibility to employment centers can perhaps best be achieved by emphasizing relocation within the general environs of the airport. In many cases with large commercial airports, the airport proper is a prime employer. For example, Miami International Airport is estimated to account directly or indirectly for up to 20 percent of the metropolitan area's employment base.

Similarity of socio-economic characteristics of a neighborhood may be a particular problem for some relocation efforts. Residents in the Neptune Road area of Logan Airport have objected to assimilation into areas without similar characteristics. They thus have been reluctant to leave on a voluntary basis. As would be expected, demographic factors would be of lesser importance for a young, mobile professional than for an elderly resident with strong local ties.

The nature of the replacement structure sometimes transcends comparability; i.e., the replacement housing unit should provide basic amenities such as running water, indoor toilets, etc., even if not present in the orginal housing.

Areas with housing surpluses may have most of the mentioned attributes with the possible exception of demographic characteristics. But, as mentioned, housing stock disequilibria may well be the norm rather than the exception, especially for tenants trying to secure apartment units in an era of rapid condominium conversions. One way to minimize problems in securing replacement housing is to stagger relocation over time to avoid a massive exodus from the project area. This option does have certain disadvantage, such as maintenance of agency staff, checkerboard patterns or desire to utilize acquired land for redevelopment/airport expansion purposes.

ELIGIBILITY

The magnitude of the soundproofing/relocation program depends upon the numbers and types of structures eligible to receive the benefits of the program. People, in their initial reaction to the concept of airport noise alleviation, usually think only of residences. There are many reasons, however, to contemplate extending program benefits to neighborhood stores, small businesses, schools, churches, etc. These raise a number of issues relative to equitable treatment, cost and social impacts.

Another set of issues concerning eligibility involves questions of timing. For example, should eligibility be limited to present property owners? Should a time limit be set on acceptance of assistance offers? Is future eligibility, if any, determined by present or future noise contours? The various answers to such questions greatly influence the magnitude of the program.

Other eligibility issues are not as easy to classify, but are unique in themselves. For example, should eligibility be extended to persons in high noise areas if the noise is mainly non-airport related? Again, is eligibility a matter of individual homeowner choice, or a matter for the local government of the area in which he lives?

Program Coverage

It is necessary to consider the desirability of extending the soundproofing/relocation program to various classes of non-residential structures. Non-residential structures house activities that can be classified in classical economic terms as sheltered or exposed. Sheltered activities produce goods or services consumed in the local area while the goods and services produced by exposed activities are consumed outside of the area. If the local area is defined as that within the L_{dn} 65 dB contour, then the factors to be discussed are those bearing on the eligibility of these two classes of activities to receive the benefits of the soundproofing/relocation program.

This section discusses issues related to the eligibility of exposed activities such as industries and commercial activities. The next section discusses one class of sheltered activities, public buildings such as schools and hospitals.

There are a number of factors which may influence the eligibility of exposed activities such as industries and commercial establishments to receive the benefits of a noise alleviation program. Among these are:

- Compatibility of the activity with various sound levels
- Self-noise generated by the activity
- The effects of redevelopment.

These factors are discussed in the following sub-sections.

Noise Compatibility. Eligibility for inclusion in a soundproofing/relocation program depends upon the degree to which noise interfers with the normal functions of the activity. There is general agreement that the activities of most heavy industries are little affected by noise, while mental activities are greatly affected by noise. Between these two extremes, however, there is some debate as to the noise levels at which an activity is seriously affected.

One set of noise compatibility values has been generated by the FAA as part of a set of interim regulations on airport noise compatibility planning programs. These Part 150 regulations prescribe a set of planning actions that an airport proprieter may take to reduce the impact of airport noise on neighboring land uses. In these regulations, the FAA has defined sound levels (Ldn) which are compatible with various land uses. Table 2.2 has been reproduced from Appendix A of the Part 150 regulations.

The categories, "Commercial" and "Manufacturing and Production", in Table 2.2 are (with the exception of "Retail Trade-General") the types of exposed activities discussed in this section. Such activities do not depend on the economy of the immediate area in which they are located.

The impacted area at any particular airport will not have all the commericial/manufacturing activities listed. Absence of some activity could

TABLE 2.2

LAND USE COMPATIBILITY WITH YEARLY DAY-NIGHT AVERAGE SOUND LEVELS

Land use	Yearly day-night average sound level (L_{dn}) in decibels					
	Below 65	65–70	70–75	75–80	80–85	Over 85
Residential:						
Residential, other than mobile homes and transient lodgings	Y	¹N	¹N	N	N	N
Mobile home parks	Y	N	N	N	N	N
Transient lodgings	Y	¹N	¹N	¹N	N	N
Public use:						
Schools, hospitals and nursing homes	Y	25	30	N	N	N
Churches, auditoriums, and concert halls	Y	25	30	N	N	N
Governmental services	Y	Y	25	30	N	N
Transportation	Y	Y	²Y	Y	⁴Y	⁴Y
Parking	Y	Y	²Y	Y	⁴Y	N
Commercial use:						
Offices, business and professional	Y	Y	25	30	N	N
Wholesale and retail—building materials, hardware and farm equipment	Y	Y	²Y	³Y	⁴Y	N
Retail trade—general	Y	Y	25	30	N	N
Utilities	Y	Y	²Y	³Y	⁴Y	N
Communication	Y	Y	25	30	N	N
Manufacturing and production:						
Manufacturing, general	Y	Y	²Y	³Y	⁴Y	N
Photographic and optical	Y	Y	25	30	N	N
Agriculture (except livestock) and forestry	Y	⁶Y	⁷Y	⁸Y	⁸Y	⁸Y
Livestock farming and breeding	Y	⁶Y	⁷Y	N	N	N
Mining and fishing, resource production and extraction	Y	Y	Y	Y	Y	Y
Recreational:						
Outdoor sports arenas and spectator sports	Y	⁵Y	⁵Y	N	N	N
Outdoor music shells, amphitheaters	Y	N	N	N	N	N
Nature exhibits and zoos	Y	Y	N	N	N	N
Amusements, parks, resorts and camps	Y	Y	Y	N	N	N
Golf courses, riding stables and water recreation	Y	Y	25	30	N	N

*The designations contained in this table do not constitute a Federal determination that any use of land covered by the program is acceptable or unacceptable under Federal, State, or local law. The responsibility for determining the acceptable and permissible land uses remains with the local authorities. FAA determinations under Part 150 are not intended to substitute federally determined land uses for those determined to be appropriate by local authorities in response to locally determined needs and values in achieving noise compatible land uses.

Key

SLUCM—Standard Land Use Coding Manual.

Y (Yes)—Land Use and related structures compatible without restrictions.

N (No)—Land Use and related structures are not compatible and should be prohibited.

NLR—Noise Level Reduction (outdoor to indoor) to be achieved through incorporation of noise attenuation into the design and construction of the structure.

25, 30, or 35—Land use and related structure generally compatible; measures to achieve NLR of 25, 30, or 35 must be incorporated into design and construction of structure.

[1] Where the community determines that residential uses must be allowed, measures to achieve outdoor to indoor Noise Level Reduction (NLR) of at least 25 dB and 30 dB should be incorporated into building codes and be considered in individual approvals. Normal construction can be expected to provide a NLR of 20 dB, thus, the reduction requirements are often stated as 5, 10 or 15 dB over standard construction and normally assume mechanical ventilation and closed windows year round. However, the use of NLR criteria will not eliminate outdoor noise problems.

[2] Measures to achieve NLR of 25 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

[3] Measures to achieve NLR of 30 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

[4] Measures to achieve NLR of 35 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

[5] Land use compatible provided special sound reinforcement systems are installed.

[6] Residential buildings require an NLR of 25.

[7] Residential buildings require an NLR of 30.

[8] Residential buildings not permitted.

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change the allowable sound levels considerably. For example, in the manufacturing category, the absence of photographic and optical industries changes the allowable L_{dn} from 70 dB to 80 dB. Thus, for any given airport, noise compatibility will have to be determined using classifications specified more precisely than the classifications given in Table 2.2. This will require a fairly detailed inventory of the affected industries and commercial establishments in the area.

If the presented L_{dn} values are accepted, then the soundproofing and relocation boundaries selected for residences may be unduly restrictive for the commercial manufacturing cases considered here. If the noise reduction levels shown in the table (which apply to new construction) can be achieved by soundproofing existing structures, then the soundproofing zone could be between L_{dn} 70 to 80 dB. This would be a considerable reduction in area from that included within the residential bounds of the 65 L_{dn} to 75 dB contour. Similarly the relocation zone boundary could be moved into the L_{dn} 80 dB line, if "should be prohibited" in the table is interpreted as being equivalent to "relocate".

Self-Noise. Manufacturing activities that generate considerable self-noise would not be eligible for coverage under the soundproofing/relocation program envisioned herein. The FAA view, as demonstrated in Table 2.2, is that manufacturing activities, aside from livestock raising and precision manufacture, can tolerate noise levels up to L_{dn} 85 dB. Offices associated with such enterprises must, of course, be soundproofed. This allowable high noise level is based on studies showing that annoyance from a given noise level decreases as the background noise level increases.

Noise tolerant activities are prime candiates for exclusion in airport noise relocation zones. Manufacturers with a high self-noise level are one type of noise tolerant activity.

Redevelopment Effects. Exclusion of commercial/manufacturing activities could forestall redevelopment efforts. Several objectives in undertaking a soundproofing/relocation program, in addition to securing alleviation of the noise problem, involve clearance and redevelopment of the impacted area, or use of the area for airport purposes. The impact of excluding this type of activity on any redevelopment effort depends on the type of program offered, the noise compatibility of the activities and the fraction of the noise impacted area occupied by the activity.

A number of types of mandatory and voluntary relocation programs are possible. These could be analogous to the residential relocation programs (voluntary or mandatory) discussed previously. However, rather than exploring all these program types, only the voluntary program is consiered at this time. In this program type, the activity could accept or reject voluntarily an offer to relocate. In rejecting the offer the activity does not agree to any conditions, such as surrendering the right to sue for noise damages.

When this type of program is presented to noise tolerant (up to L_{dn} 85 dB) and noise sensitive manufacturing activities the probable reactions are likely to be as shown in Table 2.3. Four combinations are shown of including or excluding activities from the program with noise tolerant or noise sensitive activities. In three of the four combinations, the probable result is that the industry will not move, and thus hinder future redevelopment of the area for other uses.

Excluding activities from the program means the operator was not made a relocation offer. If such excluded activities are not to become a hinderance to the redevelopment program, they can be persuaded to relocate only by providing them some especially attractive incentives provided external to the basic redevelopment program.

Even including an activity in the program does not allow clearance of the area. As shown in Table 2.3, a noise tolerant industry is not likely to accept an offer to relocate unless it is especially attractive financially.

Finally, a "hold-out" activity may not hinder redevelopment if it occupies only some small fraction of the redevelopment area, or if it is compatible with the proposed type of redevelopment. Obviously, noise tolerant industry is compatible with a program to redevelop a noise impacted

TABLE 2.3

EFFECT ON REDEVELOPMENT OF INCLUDING OR EXCLUDING NOISE SENSITIVE AND NOISE TOLERANT MANUFACTURING ACTIVITIES

	Noise Sensitive		Noise Tolerant	
	Included in Program	Excluded from Program	Included in Program	Excluded from Program
Probable Reaction to Voluntary Program	Move	Stay	Stay	Stay
Does Potential for Noise Damage Suit Exist?	No	Yes	No	No
Is Redevelopment Hindered?	No	Yes	Yes	Yes

residential area such as an industrial park containing other noise tolerant industries.

Inclusion of Public Buildings, Such As Schools and Hospitals

Although measurements of aircraft noise on vulnerable populations in schools and hospitals are rare, it has been recognized that such impacts exist and regulations pertaining to the use of these structures were developed by the ANCLUC program. Thus, in principle, public buildings should be included in the programs. However, some economic factors should also be included in the eligibility criteria and some of these factors are discussed below.

Prevailing Federal government perceptions, court decisions and the Uniform Relocation Act emphasize that those who are affected by aircraft noise should be compensated. A fairly recent report to the Congress (Reference 12) recommended that public buildings should be covered by the program. The report estimated that approximately 1,100 schools and 90 hospitals should be soundproofed. These structures could accommodate 700,000 pupils and 31,000 patients, respectively. The "rehabilitation" (soundproofing) costs were estimated to be $148 million and $56 million for schools and hospitals, respectively. The benefit of soundproofing schools was said to be $5.5 million worth of teaching time recovered and energy savings per year. For hospitals the energy savings were estimated to be $0.25 million per year.

In light of these beliefs, public buildings should not be excluded in principle from the soundproofing/relocation program, and compatibility criteria for these structures can be found in Part 150. Moreover, financial aid could be obtained from Federal grants, provided a multiple objective policy could be defined for such buildings (such as energy conservation). However, other considerations should be included when developing specific eligibility criteria for such buildings, specifically, the economic relationships between these buildings and the rest of the community.

FUNDING

A number of important financial issues will arise when planning for a soundproofing/relocation program. In general, there will be four types of funding issues. One type of issue will concern authority or responsibility. For example, will financing be undertaken by the airport authority, the city, the state or some other groupµ Another set of issues deals with the funding mechanisms to be used, i.e., bond issues, ADAP funds, noise charges, accumulated revenue, etc. This leads immediately to a third set of issues: those dealing with the continuing sources of revenue that can be used to retire any bonds which may be issued. Such souces include landing fees, taxes, airport concession income, etc. Finally, there is a set of issues which relate to the financial arrangements at the airport under consideration to the finances of other airports and to the financing of related programs.

While responses to the issues raise complicated concerns and perceptions, a measure of the financial requirements for a comprehensive soundproofing/relocation program may be gained in the first instance by examining noise fees as a source of revenues. If the fees are extraordinarily high, concerns with shifting demand patterns or, more basically, financial viability arise. If the fees are low, on the other hand, many related concerns lose much of their importance.

Noise Fees

Noise charges, as they have been suggested, in theory should be set equal to the marginal damage cost incurred at the optimal level of pollution. In turn, the optimal level of pollution is determined by the equivalence of marginal abatement costs and marginal damage costs. It is stressed that market imperfections, including the very existence of detrimental externalities themselves, may be such as to leave no indication as to which direction to take in modifying the price structure for such alleged misallocations. Therefore, it would be a more pragmatic approach to establish environmental quality standards and then use charges to secure those standards. Simply, a model requires the charge to be set equal to marginal abatement costs for each firm so as to achieve the overall quality standard. This is held to be the least cost approach to achieving the standard, since marginal abatement costs are equalized for each firm.

One procedure for aircraft noise abatement would set a fee for each type or series of aircraft, and for each hour of the day. The fees would be set to balance demand with capacity, and they would be adjusted, as needed, to maintain this balance. Noisy aircraft would pay more than quiet aircraft; at peak hours, large aircraft would pay more than small aircraft; and overall, the fees would be higher in peak hours than in off-peak hours.

Aircraft are already assessed a landing fee at airports; a noise charge could easily be an additional landing fee. The noise charge could be viewed as an approach that would be more cost effective--produce more quiet for less money--than restrictive governmental regulations because it could provide monetary incentives to the airlines to voluntarily adopt less noisy practices in order to reduce their noise charges. These charges would provide funds for local noise abatement programs such as soundproofing of dwellings, schools and hospitals, purchase of land for buffer zones, and relocation of impacted residents. More importantly, these practices may well reduce future noise exposure levels and thereby reduce total program costs.

The Foreign Experience with Noise Fees. The following is a discussion of noise charges which exist in other countries. These are presented merely as examples of systems and to whom the charges are directed. The system applied to the Amsterdam Schiphol Airport (Reference 13) in the Netherlands was to devise an "Aircraft Noise Overall Index" (ANOI) based on the hypothesis that loudness (noise as subjectively perceived) doubles for each 10 dB increment. (Surveys show that every 10 dB increase of noise level produces a twenty-point increase in the percentage of people seriously annoyed.) These factors were combined to develop an indicator:

$$I = 2\,(L_i - L_n) \times 2^{(L_i - L_n)/10}$$

where: I = impact indicator
L_i = noise level
L_n = annoyance threshold

The ANOI index would be:

$$\text{ANOI} = F_i PD_i I_i$$

where: F_i = the area in the noise footprint of an aircraft at noise level i
PD_i = population density in F_i
I_i = impact indicator in F_i.

The rate of change (α) could be calculated by dividing the cost of local action at this airport by the number of ANOI units produced at the airport. Each aircraft would then pay a charge for each landing or takeoff equal to

$$\alpha_i \text{ ANOI}_i.$$

This system was applied to the case of Amsterdam's Schiphol Airport, and the charge per aircraft would range to approximately $303 (U.S.) for a noncertified, four engine aircraft (the noisiest). This approach bases the charge on a reliable noise impact indicator and calculates the rate according to the cost of a predetermined program of local noise abatement measures around the airport applying the charge.

In France, a special charge designed to finance noise insulation of buildings around Charles de Gaulle and Orly Airports has been in operation since 1973 (Reference 14). According to this scheme, each passenger is paying a charge of one franc on domestic flights and three francs on international flights. The funds are collected by the airport and allocated by a special commission for financing as much as two-thirds of the cost of noise insulation for private and public buildings. This charge is not related to the noise level of the aircraft, however. For this reason, implementation of a new system is now under consideration (Reference 14). The basis for the charge would be the noise emission in EPNdB as measured under the ICAO Annex 16 noise certification procedure, called characteristic noise (CN), compared with the maximum noise level authorized under Annex 16, called reference noise (RN). Aircraft would be classified in one of four groups:

- Category I: if CN>RN
- Category II: if CN is lower than RN by a maximum of 9 EPNdB
- Category III: if CN is lower than RN by no less than 9 EPNdB and no more than 18 EPNdB
- Category IV: If CN is lower than RN by more than 18 EPNdB.

The charge could be calculated by applying the following rates:

- Category I: α
- Category II: $1/2\alpha$
- Category III: $1/4\alpha$
- Category IV: 0α

where the basic rate is the amount of francs per ton maximum takeoff weight Such a charge could amount to 5 to 10 percent of the landing charges for the category.

In Japan, a special landing charge has been operating since September 1975 (Reference 15). Its major objective is to finance local noise abatement measures. The charge is a function of the aircraft weight and noise level. In 1979, the charges by type of aircraft were as follows:

NOISE CHARGES AT JAPANESE AIRPORTS

Type of Aircraft	Charge Yen	 US$
Boeing 747 SR	215,420	1,034
DC8	196,680	944
L1011	169,100	812
Boeing 727	101,240	487
DC9	69,280	333

The charge is paid by airlines, and part is shared among the passengers by including flat rate amounts in the price of tickets (for domestic flights only).

Miami Airport - An Illustration. The funding required to implement an airport noise soundproofing and relocation effort can be acquired through the use of landing fees or passenger surcharges. If landing fees are used, they will be required to be equitable so noisier aircraft have higher noise fees. The charge was noted by the President's Council in Wage and Price Stability as less disruptive of interstate commerce than imposing curfews or the grounding of noisy planes (Reference 16). To quantify the impacts of a noise charge and the development of program funds for an airport soundpprofing and relocation program, a methodology was developed that enabled an assessment of the manner in which noise charges could be allocated over time to accumulate program funds. Table 2.4 develops a charge for each operation of an aircraft type based on the following assumptions:

TABLE 2.4

NOISE CHARGE PER AIRCRAFT OPERATION
MIAMI RPORT

Aircraft Type	EPNL	1979 N_i (000)	1979 F_i/N_i $	1990 N_i (000)	1990 F_i/N_i $	2000 N_i (000)	2000 F_i/N_i $
DC-9-32	104	7.45	$ 57.01	6.14	$ 65.59	-	-
DC-9-15	104	4.31	57.62	2.09	65.59	-	-
BAC-111	104	-	-	-	-	-	-
727-100	104	18.62	57.01	-	-	-	-
737W/SAM	104	3.39	57.62	4.84	65.59	-	-
707-320 B/C	105	2.88	72.33	-	-	-	-
707-120B	105	0.22	72.33	-	-	-	-
720B	105	0.07	69.88	-	-	-	-
DC-8-55	105	2.81	71.72	-	-	-	-
DC-8-30	105	0.44	72.33	-	-	-	-
DC-9W/SAM	105	1.53	72.33	2.81	82.76	-	-
727W/SAM	105	15.91	72.33	11.98	82.14	-	-
727ADV W/SAM	105	15.91	72.33	12.03	82.14	-	-
DC-9-80*	102	-		6.53	65.59	6.78	74.79
DC-8-61/63	106	3.14	90.72	-	-	-	-
A-310*	102	-	-	4.48	41.07	4.49	47.20
B-767*	102	-	-	4.50	25.75	4.49	47.20
B-757*	102	-	-	3.22	41.07	3.23	47.20
A-300	103	1.13	45.36	3.88	52.11	3.58	59.46
DC-10-10	104	4.09	57.01	1.74	65.59	1.45	74.79
L-1011	104	10.22	57.01	5.55	65.59	5.11	74.79
DC-10-30	104	1.10	57.62	3.10	65.59	3.22	74.79
STRETCH	104	0.47	57.62	3.15	65.59	3.06	74.79
747-200	104	0.11	55.78	7.02	65.59	30.78	74.79
747-100	105	0.99	71.72	3.06	82.14	-	-
747 STRETCH	105	0.11	72.33	4.04	82.14	11.85	94.40
B-747 TYPE	105	-	-	-	-	4.70	94.40
TOTAL		94.90		90.16		82.74	

*New Aircraft Type After 1979.

- Total program (airport soundproofing and relocation) costs for compatibility at the Miami International Airport (MIA) in the year 2000 would be $122,634,000. Program costs would be considerably less if compatibility controls and noise abatement flight tracks were employed to reduce noise exposure levels (see Chapter V).

- Departures (in 000's) are presented by aircraft type and by year (1979 baseline, 1990 and 2000). Note that there are fewer aircraft types in use in year 2000 as compared to 1979 and there are fewer departures, but aircraft capacity is greater in year 2000 as compared to 1979 (see Chapter IV).

- Determining actual charges for specific fleet operations requires a schedule of charges based on the decibel level (EPNL), time-of-day and possibly the runway. As the noise level increases, the total charge, depending upon the environmental damage caused by noise emissions, also increases. The EPNL for the various aircraft types are based upon Federal Aviation Regulation 36 Stage 2 and 3 and different aircraft weights. For those aircraft that were not in service prior to 1979, EPNL levels were based on the lowest of existing measures. Thus, it is assumed that newer models of aircraft will cause less of an noise impact than older models.

- It is further assumed, for reasons of simplicity, that there will be no time value of money. Thus, there will be discounting of program funds to 1979. Therefore, the total program costs of $122,600,000 is in 1979 dollars. A straight line method of desired funding for the period 1980 to 2000 is also assumed. The funds accumulated will be at the same level each year, or $6.13 million.

The total program cost (T) can be acquired in a 20-year period (1980-2000) through the charge F_i/N_i on each aircraft operation. This is given by:

$$F_i/N_i = T \frac{10^{EPNL_i/10}}{\Sigma_i^n \; N_i \, 10^{EPNL_i/10}}$$

where F_i = the fee per aircraft type for some period of time based on the aircraft's noise level

i = the given aircraft type

N_i = total aircraft departures for the same period of time.

Table 2.4 does not take into consideration the possible shift from one aircraft type that may be noisier to another aircraft type that would be quieter, nor does the table consider weighting the costs based on nighttime arrival/ departure versus daytime arrival/departure.

The magnitude of these charges per aircraft operation is low, the mean being $65.24, $64.54 and $73.69 for 1979, 1990 and 2000 respectively. While the airlines are shifting to quieter aircraft over time, this charge does not generate a strong incentive for airlines to retrofit noisy aircraft. Further, the per operation charge would be even less were compatibility and noise abatement flight tracks employed.

The 1979 landing charge by Miami is $21 for a DC9, $44 for a Boeing 707 and $118 for a Boeing 747.* These landing fees are average daytime landing values and include pertinent costs for landing, lighting, passenger service charges paid by airlines, parking, security, park zone and terminal navigation fees. Landing fees at different airports fluctuate widely. The fluctuations should be the result of different traffic patterns infrastructure costs and the services provided. Table 2.5 shows the representative charges for seven U.S. airports.

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*From Table 2.4, the 1979 noise charge would be $57 for a DC-9-32, $72 for a Boeing 707 and $58 for a Boeing 747-200.

TABLE 2.5

Representative Landing Fee (dollars) (U.S. Airports)*

Airport	DC 9	B 707	B 747
Kennedy, NY	1,421	1,883	3,616
Dallas/Fort Worth	125	225	552
Detroit	766	1,205	3,039
Los Angeles	79	165	446
Miami	21	44	118
San Francisco	48	100	271
Washington National	235	380	967

The noise fee is an item that airlines would pass directly to the customer. The increase in individual ticket prices would not encourage passengers to shift from noisier to quieter aircraft. A "noise surcharge" may be a method to make the public aware of the problem, and of the relocation and soundproofing program. However, a noise surcharge may require frequent adjustments, thus making the implementation of the fee less efficient than was proposed with a straight-fee operation.

The above example of a noise fee is only for illustration purposes, demonstrating a potential methodology that could be incorporated (with modifications) to fund the eventual program costs for soundproofing and relocation of private residences exposed to airport noise levels exceeding L_{dn} 65 dB and 75 dB, respectively. Other features that would require incorporation into such a plan are the time-value of money and discounting of future cash flows.

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*On a per passenger basis, the average landing fee for the seven representative airports (assuming a 70 percent load factor) would be $4.77, $5.47 and $4.05 for the DC9, B707 and B747, respectively. The per passenger noise charge (from Table 2.4) would be $0.70, $0.69 and $0.18.

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III. REPRESENTATIVE AIRPORT DEVELOPMENT METHODOLOGY

This chapter covers the development of a set of analytical tools which can integrate the sundry parameters which affect airport noise exposure and can then be used to forecast the ramifications of a series of noise abatement planning scenarios. The generation of a comprehensive data base and the determination of a set of representative airports, or Rports, is a necessary first step in the development of such analytical tools. This chapter describes the procedure employed to generate such a data base and set of representative airports.

BACKGROUND

There are two alternative methods which can be employed for estimating the national exposure due to aircraft noise. The first method requires a noise exposure calculation for each airport of interest and then summing to determine total exposure. Since this first method would require considerable time and resources to implement and complete, it is generally regarded as an impractical and undesirable approach. The second method involves developing model airports, calculating noise exposure for these model airports, and scaling the results to derive national noise exposure estimates. The model airports, referred to as Rports, permit forecasts and sensitivity analyses to be performed for variables such fleet size, fleet composition, noise levels, flight procedures, and flight tracks by studying only several airports instead of many.

The representative airports represent a number of distinct categories of airports, that is, subsets of the total set of airports. The requirement is that the noise exposure around a Rport, specified in terms of area and population exposed (as well as other pertinent socio-economic and demographic considerations), approximates the total noise exposure for all of the subset it represents when multiplied by an appropriate scaling factor. Also, the sum of the noise exposure for each subset should approximate the noise exposure (area, population, etc.) of all sets of airports.

IDENTIFICATION AND GENERATION OF REQUIRED DATA BASES

Since it could not be predicted beforehand just which variables might prove most useful in defining distinct categories of airports, the initial steps in the methodology might charitably be described as casting the net as widely as possible. After the initial exploratory period, however, it was rapidly determined that only a relatively few real fish had been caught in the net. Thus, it was possible to define categories of airports on the basis of rather few variables with considerable confidence that the most important factors were being taken into consideration.

The identification and generation of the data bases required to determine a single Rport that represents a distinct category of airports were divided into two parts: (1) the development of an airport/aircraft data base which could be used to define distinct categories (or sets) of airports and (2) the development of an airport/aircraft data base necessary to run the FAA's Integrated Noise Model (INM) and the National Aeronautics and Space Administration's Aircraft Noise-Levels Annoyance Model (ALAMO)* for selected airports from each airport category.

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*The ALAMO is an airport community noise impact assessment model currently operational on the NASA Langley Research Center's (LRC) Computer System (Reference 1).

Data Required To Define Distinct Categories of Airports

The airport/aircraft data identified as requirements for developing distinct categories of airports include the following:

- Number of annual commercial jet air carrier operations for each airport considered
- Airport noise produced by the flight operations of commercial jet air carrier aircraft
- Selected socio-economic and demographic variables which describe the surrounding airport community
- Airport/aircraft parameters which are specific to each airport considered.

Number of Annual Commercial Jet Air Carrier Operations. This variable was considered essential because it is one of the determinants of the total noise produced by aircraft operations. The number of annual (calendar year 1979) commercial jet air carrier departures by aircraft type was obtained from Table 7 in Reference 2. A computer file containing these aircraft operations data was coded and installed on the EPA's NCC computer system. The file, henceforth referred to as the Airport Activity Statistics (AAS) file, included aircraft operations data for 304 airports serving certificated route air carriers.

Airport Noise Produced By Commercial Jet Air Carrier Operations. The airport noise produced by commercial jet air carrier operations was represented by two noise measures: (1) Fleet Noise Level (FNL) and (2) Airport Noise Index (ANI). The concept of FNL provides a method for evaluating the noise status of fleets of aircraft. It provides a single figure of merit so that fleets of aircraft can be compared with each other with respect to noise. The concept of FNL is very flexible in that it can be applied to a wide variety of situations. For example, a general FNL could be calculated for all airports or any subset of airports in the U.S. The calculation could be done for any particular airline or any combination of airlines. For a detailed explication of the concept of FNL, see Reference 3.

Even a cursory examination of the equation for FNL will reveal that it is an average of acoustical energies. Thus, it is possible that two fleets might have the some average noise level, but could produce different levels of total acoustical energy. In other words, two airlines or airports might have the same FNL, but one of them might have a much greater number of operations. A measure that would be sensitive to differences in total energy is the Airport Noise Index (ANI) which approximates day-night sound level calculated without the night weighting. ANI is calculated by the following formula:

$$\text{ANI} = \text{FNL} + 10 \log (D/365) + 53$$

where: ANI = airport noise index in dB
FNL = fleet noise level in dB
D = number of yearly departures.

The Federal Aviation Administration (FAA) provides information on noise levels produced by all aircraft in service in the U.S. airline fleet at the three measuring points specified in Federal Air Regulation (FAR) Part 36: sideline, takeoff, and approach. Noise levels are provided for alternative engine installations in the same model of aircraft. Since this information is much more detailed than the aircraft information given in Reference 2, which does not give the engines installed in the aircraft types, it is necessary to use both a maximum and a minimum value for calculating FNLs. These values are the levels for the noisiest and quietest engine installations, so that the total range of variation in noise levels for a particular type of aircraft can be covered. Thus, a maximum and minimum FNL is found for each of the FAR Part 36 measuring points, a total of six FNL values for each airport. Further, it is possible to calculate an ANI value corresponding to each FNL, a total of 12 noise measures. It was felt important to include all 12 measures in the initial data base because it was impossible to predict what intercorrelations might exist among them or how they might contribute to the definition of airport categories.

Selected Socio-Economic and Demographic Variables. In addition to the aircraft operations and noise level data, consideration of certain socio-economic and demographic variables was necessary in developing distinct categories of airports. That is, airport noise is a problem only if there is an impact on the surrounding population. The representative airport, then selected, should be presented not only in terms of noise levels, but in terms of population exposed and the demographic characteristics of this population as well. Only in this manner can the Rport concept be effectively used to project national and airport-specific data on the benefits of noise control actions.* The variables selected for inclusion into the aircraft/airport data base were obtained from the FAA's Airport Information File (AIF).** These variables included:

- Total population
- Number of households in 1975
- Total number of incomes
- Total number of homes
- Total number of renters
- Average home value
- Average monthly rent
- Population change from 1970 to 1975
- Population growth rate.

Values for each of the variables were determined for areas within a five-mile and a ten-mile radius of the airport center and are based on 1970 census data, except where indicated otherwise. The five-mile radius was used because it included the areas that would be most severely affected by noise, and the ten-mile radius was used because it is about the limit of noise effects.

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*The integration of noise and demographic factors represents a major improvement on prior studies employing the Rport concept. For example, in Reference 4, four Rport classes were developed according to aircraft types using the air carrier airports. Sample airports from each class were then selected based on operational characteristics (e.g., runway length, day/night distribution of operations, etc.) and number of airport operations. The character of the surrounding communities/population was not a factor in final Rport selection.

**A computer tape of the AIF was obtained from the FAA and installed on the EPA's NCC computer system. A description of the elements of the AIF is presented in Reference 5.

Data were extracted from the AIF for only those airports with scheduled commercial jet operations, for the noise effects of propeller aircraft are slight in comparison to jet aircraft. It was found that the AIF contained information for 298 airports which meet this criterion.

Airport/Aircraft Parameters Specific To Each Airport. A number of variables which were considered to be airport-specific were obtained from the AIF and included in the airport/aircraft data base. These parameters were:

- Number of miles from the airport to the nearest city
- Airport area in square miles
- Number of hard surface runways
- Number of IFR runways
- Length of longest runway
- Practical daily operations capacity
- Number of hours open per day
- Number of cargo operations during the time period from 1990 to 2159
- Number of scheduled jet operations during the time period from 1990 to 2159
- Number of scheduled jet operations per day (24 hour period)
- Number of 4-engine narrow body operations during the time period from 0700 to 2159
- Number of 4-engine narrow body operations during the time period from 2200 to 0659
- Number of 4-engine wide body operations during the time period from 0700 to 2159
- Number of 4-engine wide body operations during the time period from 2200 to 0659.

These variables comprise almost all of the airport-specific variables in the AIF that appeared to hold at least some promise for contributing to a definition of airport categories. An attempt was made to use a few other variables in the AIF (such as computed daily fuel consumption and noise exposure forecast), but they proved to contain so many missing values that they could not be used.

Combined Airport/Aircraft Data Base. The airport/aircraft data obtained from the AIF and the AAS file were combined to form a single data base. The combination of the two files resulted in a data base representing 277 airports. The number of airports contained in the data base was reduced to 236 by considering only those airports which handled four (4) or more scheduled large jet (greater than 75,000 pounds) operations per day. Less than four flights per day would not constitute a noise problem. These 236 airports accounted for over 10 million air carrier operations performed in calendar year 1979, or about 95 percent of the total jet operations.

Input Data Required to Run the FAA's INM

The FAA's INM is a collection of computer programs which can calculate the aircraft noise environment in the vicinity of an airport given certain information concerning airport location, layout, and the type and movement of its air traffic. The resulting noise environment can be described in either tabular or graphic form (see Table 3.1 and Figure 3.1).

The INM user is required to provide at least five and up to ten types of data describing the airport and its associated activity in order to run the model. Required data include the following:

- Airport altitude and temperature
- Runway configuration (number, length, and orientation)
- Flight track definition
- Approach profiles
- Traffic mix (distribution of operations by aircraft type).

TABLE 3-1

EXAMPLE OF TABULAR PRESENTATION OF INM RESULTS

```
FEDERAL AVIATION ADMINISTRATION INTEGRATED NOISE MODEL 2. 7
 EXAMPLE AIRPORT SCENARIO

----------------------------------------------------------------------------
I     I          I          I          I CONTOUR I      I               I
I PNT I    X     I    Y     I    LDN   I  AREA   I FLTS I  ITERATIONS   I
I     I  COORD.  I  COORD.  I DECIBELS I SQ. MI. I USED I               I
----------------------------------------------------------------------------
I 101 I     25.5 I   3194.9 I    75.10 I    3.37 I   23 I        7      I
I 102 I     35.3 I   4014.9 I    75.02 I    3.37 I   23 I        7      I
I 103 I   -219.8 I   4787.2 I    74.95 I    3.35 I   23 I        7      I
I 104 I   -517.9 I   5548.5 I    74.97 I    3.32 I   23 I        7      I
I 105 I   -858.3 I   6291.4 I    74.98 I    3.30 I   23 I        7      I
I 106 I  -1208.4 I   7032.9 I    75.01 I    3.27 I   23 I        5      I
I 107 I  -1563.2 I   7772.2 I    74.98 I    3.24 I   23 I        5      I
I 108 I  -1909.6 I   8515.4 I    74.93 I    3.21 I   23 I        5      I
I 109 I  -2232.7 I   9276.7 I    75.01 I    3.19 I   23 I        8      I
I 110 I  -2338.1 I   9663.7 I    74.93 I    3.19 I   23 I        7      I
I 111 I  -2146.5 I   9530.7 I    75.06 I    3.22 I   23 I       13      I
I 112 I  -1632.6 I   8959.3 I    75.07 I    3.28 I   23 I        7      I
I 113 I  -1157.3 I   8231.1 I    74.93 I    3.34 I   23 I        5      I
I 114 I   -721.7 I   7598.4 I    75.01 I    3.39 I   23 I        7      I
I 115 I   -282.5 I   6906.0 I    75.01 I    3.44 I   23 I        5      I
I 116 I    157.0 I   6213.7 I    75.00 I    3.49 I   23 I        5      I
I 117 I    624.3 I   5543.2 I    74.99 I    3.54 I   23 I        7      I
I 118 I   1085.1 I   4869.8 I    74.97 I    3.60 I   23 I        7      I
I 119 I   1611.0 I   4246.9 I    74.98 I    3.66 I   23 I        7      I
I 120 I   2150.1 I   3633.5 I    75.00 I    3.72 I   23 I        7      I
I 121 I   2740.9 I   3072.4 I    74.98 I    3.78 I   23 I        7      I
I 122 I   3263.6 I   2449.7 I    74.99 I    3.83 I   23 I        7      I
I 123 I   3836.5 I   1871.9 I    74.98 I    3.89 I   23 I        7      I
I 124 I   4583.7 I   1548.3 I    74.97 I    3.94 I   23 I        7      I
I 125 I   5397.4 I   1541.4 I    74.97 I    3.96 I   23 I        7      I
I 126 I   6211.4 I   1640.6 I    74.92 I    3.98 I   23 I        5      I
I 127 I   7022.2 I   1556.4 I    74.98 I    4.01 I   23 I        7      I
I 128 I   7837.1 I   1540.6 I    74.98 I    4.03 I   23 I        7      I
I 129 I   8649.4 I   1609.5 I    74.98 I    4.05 I   23 I        7      I
I 130 I   9448.7 I   1769.1 I    74.98 I    4.05 I   23 I        7      I
I 131 I  10244.9 I   1947.0 I    74.95 I    4.04 I   23 I        7      I
I 132 I  11026.1 I   1718.4 I    74.96 I    4.11 I   23 I        7      I
I 133 I  11707.1 I   1274.3 I    74.95 I    4.22 I   23 I        7      I
I 134 I  12403.6 I    853.4 I    74.95 I    4.32 I   23 I        7      I
I 135 I  13183.0 I    622.0 I    74.98 I    4.39 I   23 I        7      I
I 136 I  13984.3 I    447.7 I    74.96 I    4.44 I   23 I        5      I
I 137 I  14770.5 I    227.3 I    74.99 I    4.50 I   23 I        7      I
I 138 I  15468.7 I      0.0 I    75.02 I    4.56 I   23 I        1      I
----------------------------------------------------------------------------

END
```

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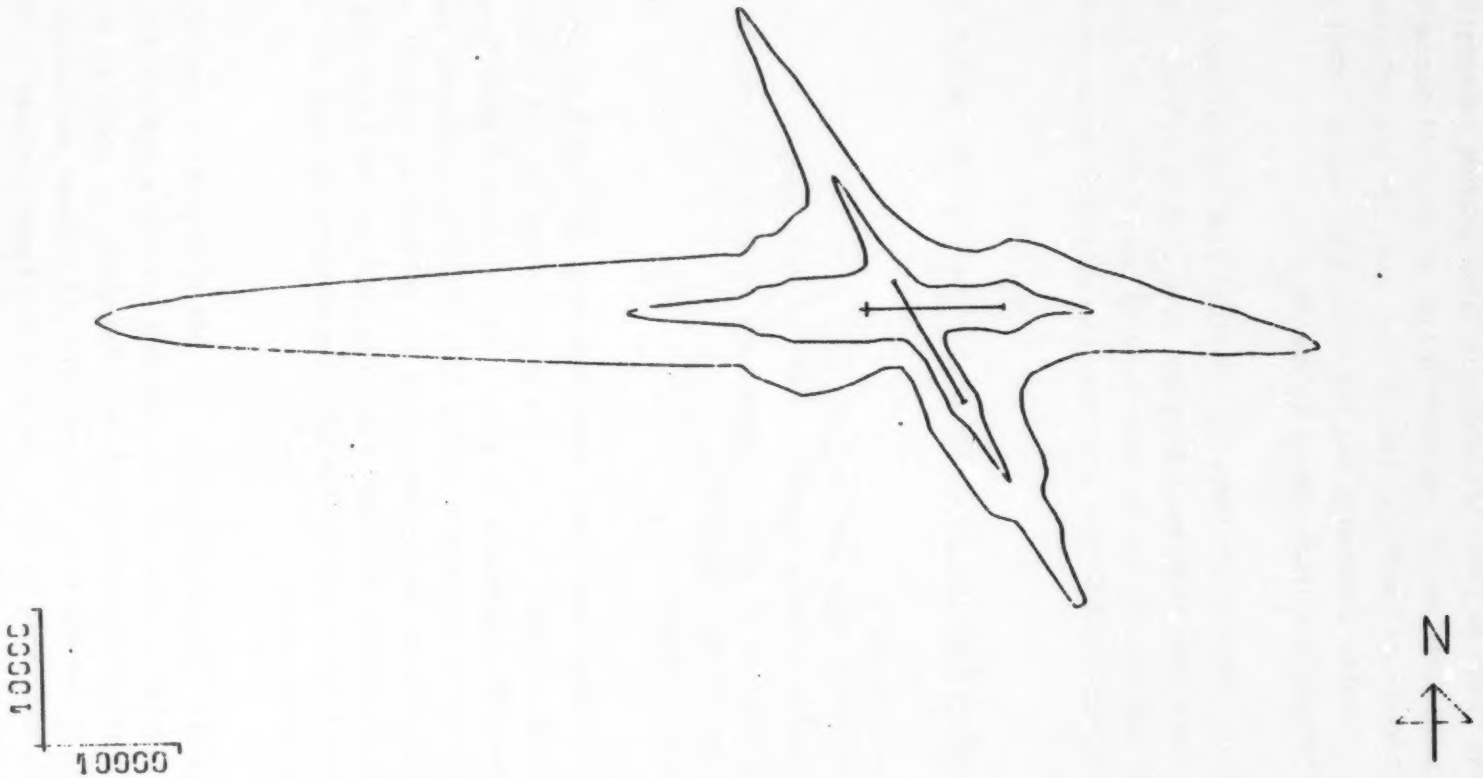

10000
10000
N

FIGURE 3.1. EXAMPLE OF GRAPHIC PRESENTATION OF INM RESULTS

In addition to the required data, the user must also provide information related to runway utilization and the distribution of aircraft operations by operation type (takeoff or landing), time of day, and, for takeoff operations, the trip length. Details concerning the INM input data coding format and other data requirements are discussed in Reference 6.

Most of the required INM data was obtained from the AIF and the AAS computer files. Data base management programs were used to extract information from both the AIF and the AAS and to generate data base files. Information presented in Reference 7 and 8 were also used to supplement or to verify data obtained from the AIF.

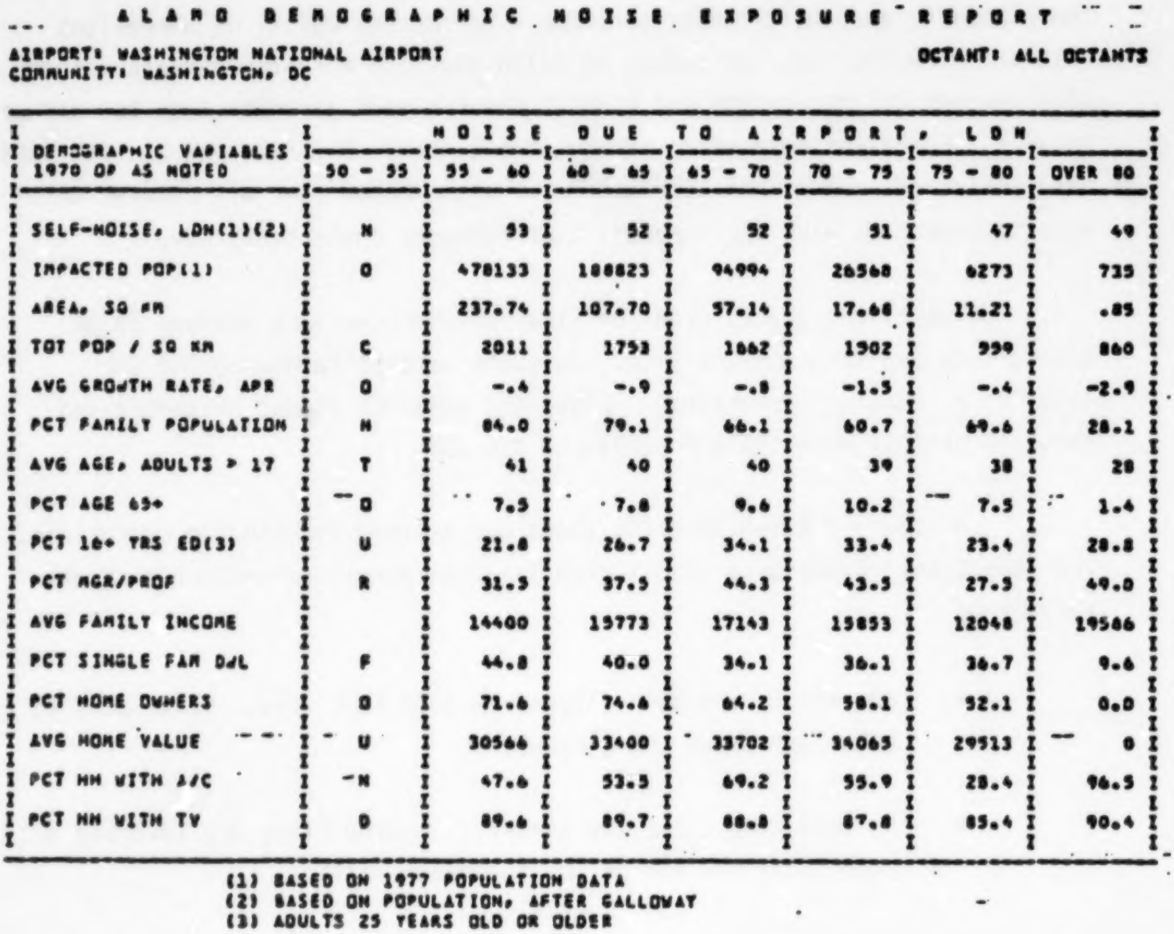
Data Obtained From the AIF. The data extracted from the AIF included:

- Runway altitude
- Airport latitude and longitude
- Variation between magnetic north and true north
- Distribution of aircraft departures by aircraft type, by trip length and by time of day
- Runway configuration.

An example of the presentation format used to display the INM data obtained from the AIF is shown on Table 3.2. As can be seen from Table 3.2, the distribution of aircraft departures is given only in terms of generic aircraft types, e.g., 2ENBDA means a 2-engine narrow body operation performed during the day. Also, the airport runway end-points are defined in terms of latitude and longitude. In preparing INM input data, the latitude and longitude values were converted to X-Y coordinate points with the airport latitude and longitude as the coordinate system center.

Data Obtained From the AAS File. The AAS file presents operations data for general classes of aircraft and does not provide a distribution of operations by aircraft/engine configuration. Therefore, in order to utilize the data contained in the AAS file, the AAS aircraft classes were matched with the aircraft types considered in INM. The aircraft types included in the AAS file and their corresponding INM aircraft types, AIF generic types, and INM

TABLE 3-2
EXAMPLE OF THE ALAMO REPORT OUTPUT



```
          A L A M O   D E M O G R A P H I C   N O I S E   E X P O S U R E   R E P O R T

AIRPORT: WASHINGTON NATIONAL AIRPORT                                          OCTANT: ALL OCTANTS
COMMUNITY: WASHINGTON, DC

---------------------------------------------------------------------------------------------------
I                     I          N O I S E   D U E   T O   A I R P O R T ,   L D N                I
I DEMOGRAPHIC VARIABLES I---------I---------I---------I---------I---------I---------I---------I
I 1970 OR AS NOTED    I 50 - 55 I 55 - 60 I 60 - 65 I 65 - 70 I 70 - 75 I 75 - 80 I OVER 80 I
I---------------------I---------I---------I---------I---------I---------I---------I---------I
I                     I         I         I         I         I         I         I         I
I SELF-NOISE, LDN(1)(2) I    N    I      53 I      52 I      52 I      51 I      47 I      49 I
I                     I         I         I         I         I         I         I         I
I IMPACTED POP(1)     I    O    I  478133 I  188823 I   94994 I   26560 I    6273 I     735 I
I                     I         I         I         I         I         I         I         I
I AREA, SQ KM         I         I  237.74 I  107.70 I   57.14 I   17.68 I   11.21 I     .85 I
I                     I         I         I         I         I         I         I         I
I TOT POP / SQ KM     I    C    I    2011 I    1753 I    1662 I    1502 I     559 I     860 I
I                     I         I         I         I         I         I         I         I
I AVG GROWTH RATE, APR I    O    I     -.4 I     -.9 I     -.8 I    -1.5 I     -.4 I    -2.9 I
I                     I         I         I         I         I         I         I         I
I PCT FAMILY POPULATION I    N    I    84.0 I    79.1 I    66.1 I    60.7 I    69.6 I    28.1 I
I                     I         I         I         I         I         I         I         I
I AVG AGE, ADULTS > 17 I    T    I      41 I      40 I      40 I      39 I      38 I      28 I
I                     I         I         I         I         I         I         I         I
I PCT AGE 65+         I    O    I     7.5 I     7.8 I     9.6 I    10.2 I     7.5 I     1.4 I
I                     I         I         I         I         I         I         I         I
I PCT 16+ YRS ED(3)   I    U    I    21.8 I    26.7 I    34.1 I    33.4 I    23.4 I    28.8 I
I                     I         I         I         I         I         I         I         I
I PCT MGR/PROF        I    R    I    31.5 I    37.5 I    44.3 I    43.5 I    27.5 I    49.0 I
I                     I         I         I         I         I         I         I         I
I AVG FAMILY INCOME   I         I   14400 I   15773 I   17143 I   15853 I   12048 I   19586 I
I                     I         I         I         I         I         I         I         I
I PCT SINGLE FAM DWL  I    F    I    44.8 I    40.0 I    34.1 I    36.1 I    36.7 I     9.6 I
I                     I         I         I         I         I         I         I         I
I PCT HOME OWNERS     I    O    I    71.6 I    74.6 I    64.2 I    58.1 I    52.1 I     0.0 I
I                     I         I         I         I         I         I         I         I
I AVG HOME VALUE      I    U    I   30566 I   33400 I   33702 I   34065 I   29513 I       0 I
I                     I         I         I         I         I         I         I         I
I PCT HH WITH A/C     I    N    I    47.6 I    53.5 I    69.2 I    55.9 I    28.4 I    96.5 I
I                     I         I         I         I         I         I         I         I
I PCT HH WITH TV      I    D    I    89.6 I    89.7 I    88.8 I    87.8 I    85.4 I    90.4 I
I                     I         I         I         I         I         I         I         I
---------------------------------------------------------------------------------------------------
             (1) BASED ON 1977 POPULATION DATA
             (2) BASED ON POPULATION, AFTER GALLOWAY
             (3) ADULTS 25 YEARS OLD OR OLDER
```

aircraft IDs are shown on Table 3.3. Based on a format similar to that shown in Table 3.3, aircraft operations data were generated from the AAS file.

INM Input Data Preparation. Using the data obtained from the AIF and the AAS file, aircraft operations data were computed for each airport considered. The determination of the number of operations for a given aircraft type at each airport was based on the operations data obtained from the AAS file, and the distributions (on a percentage basis) of operations obtained from the AIF. It should be noted that the AIF provided operations data related to trip length and time of day for each aircraft type but did not provide information related to runway utilization. In preparing the INM data bases, aircraft operations were uniformly distributed over all runways which were commensurate with the aircraft's performance characteristics.

The flight tracks used for baseline INM runs were assumed to be straight-in and straight-out (i.e., no turns were performed during the take-off or landing operations). Also, the take-off flight procedure and noise technology were those internal to the INM.

A standard 3 degree glide slope was assumed for landing operations. The operational procedures used during landing operations consisted of the following:

- Descent at approach flaps from 5000 feet above the airport to 1000 feet above the airport.
- At 1000 feet above the airport, landing flaps are selected and held until the end of the touchdown roll.
- At touchdown, reversal thrust is applied and the aircraft is decelerated to 32 knots (KTAS).

The thrust and velocity parameters used with the standard 3 degree glide slope landing procedure are part of the INM's internal data. Details concerning the INM's internal data bases are described in Reference 6.

TABLE 3-3
AIRCRAFT CLASSIFICATION FOR INM RUNS

Aircraft Types (Per AAS)	Aircraft Type (Per INM)	AIF Aircraft Types	INM Aircraft ID
A-300B	A300	2EWB	20
B-707-100 B-707-300	707-120/320	4ENB	13
B-707-100B	707-120B	4ENB	8
B-707-300B B-707-300C	707-320B/C	4ENB	7
B-720B	720B	4ENB	9
B-727-100 B-727-100C	727-100	3ENB	6
B-727-200	727 W/SAM	3ENB	30
B-727-200	727 ADV.W/S		33
B-737-200 B-737-200C	737 W/SAM	2ENB	29
B-747	747-100	4EWB	26
B-747C B-747F	747 STR	4EWB	27
B-747 SP	747-200	4EWB	25
BAC-111-200	BAC-111	2ENB	3
DC-8-10/20/30	DC-8-30	4ENB	15
DC-8-50 DC-8-50F	DC-8-55	4ENB	10
DC-8-61 DC-8-62 DC-8-63F	DC-8-61/63	4ENB	11
DC-9-10	DC-9-15	2ENB	2
DC-9-30	DC-9-32	2ENB	1
DC-9-50	DC-9 W/SAM	2ENB	28
DC-10-10	DC-10-10	3ENB	21
DC-10-30	DC-10-30	3EWB	23
DC-10-40	STRETCH	3EWB	24
L-1011	L-1011	3EWB	22

Input Data Required to Run The ALAMO

The ALAMO is an automated mathematical model which assesses the noise impact of airport operations on a given airport community. It conducts an analysis of descriptive information relative to the airport configuration, location and flight operations; noise contour data which reflects the airport community as a whole and for each of the octants defined by super-imposing a circle divided radially into eight equal parts on the community, centered at the airport.

A major task performed by the ALAMO is the generation of noise contour data. These contour data are developed using the FAA's INM. Therefore, a complete INM input data base is one requirement to run the ALAMO.

Other required input data include the latitude and longitude of the airport center (obtained from the AIF), the state in which the airport is located and two adjacent states. Using these data, ALAMO utilizes a demographic retrieval system called SITE II* to obtain a variety of information concerning the airport community extracted from the 1970 Census of Population and Housing.

PRIORITY RUNWAY AND FLIGHT TRACK STRATEGY

Generalized studies of aircraft noise impact on areas near airports when made in an effort to predict areas and population within specified contours, normally assume approach and departure flight paths on extended runway centerlines and aircraft operations distributed equally on all runways appropriate for those operations. The reason for these generalizations is that the selection of optimum distribution of operations on runways and of optimum ground tracks to fly over the minimum number of people is a time-consuming and therefore expensive task when a large number of airports are involved. In this study, calculations were made for 10 airports to determine the percent reduction of the number of people within specified contours when preferential runways and flight tracks were used. These data were then extrapolated to obtain a percent reduction in the number of people exposed to specified aircraft noise levels in the whole system of airports.

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*SITE II is a proprietary demographic data base developed by CACI, Inc.

Priority Runways

In developing a runway priority system for an airport, the population distribution around the airport was studied with an estimated L_{dn} 65 dB contour for all of the airport operations in mind. This study was made using U.S. Geological Survey maps with a scale of 1:24,000. These maps are kept current by overprinting the latest changes indicated by aerial photographs. Urban areas are shown in pink and updating revisions are shown in purple with individual buildings identified. The selection of the first priority runway is obvious if the extended centerline of one runway is over water, swamps/desert or underdeveloped farmland while the others are over urban or developed areas. However, if the urbanization is equal in all directions, there is little to be gained in reducing total population noise exposure by using one runway more than another. The total area within a given contour for a fixed set of operations is roughly the same regardless of the distribution of these operations on the several runways at an airport.

Points to remember in selecting priority runways and ground tracks are, first, that even though the contour may extend over residential areas in all directions, perhaps the tips or a significant part of the contour may extend beyond the residential area in one or more directions. Second, the flight track can be curved away from residential areas after the initial take-off and climb.

Runways in this study are identified as first priority, second priority, third priority, etc., on the basis of minimizing the number of people within the L_{dn} 65 dB contour. Most of the operations are on the first priority runway or on the first and second priority runways. The operations on the third and forth priority runways are small.

The distribution of operations on these runways is based on wind velocity and direction. The FAA has determined that aircraft may use a

15 knots (Reference 11). Information on wind velocity and direction has been obtained from the Department of Commerce's Airport Climatological Summaries for each airport (Reference 12). The data used in this study are from the "annual" Table 11A for each airport. Since Instrument Flight Rules (IFR) weather conditions, which might require the use of a different runway, exist for a small portion of the time it is assumed that the same runways would be used under IFR as under all weather conditions.

The first priority runway is used under all conditions except when the tail wind is more than 5 knots or the crosswind is more than 15 knots. The weather data indicate the percent of time that the wind is at each of sixteen points of the compass and is in one of nine wind velocity ranges. When the angle between wind direction and take-off heading (α) is less than 90° conditions are acceptable, except when the crosswind component (wind velocity times sin (α) is more than 15 knots. When the wind is more than 90° from the take-off heading, an additional limitation is that the tailwind component (wind velocity times cos (α) may not be more than 5 knots. On this basis, all time intervals in the annual Table 11A for the airport are assigned to the first priority runway if the mid-wind velocity for the band meets the above acceptable criterion. The total of these time intervals indicates the percent of the time when the first priority runway can be in use. It is assumed that operations on that runway are the same percent of the total operations as the percent time that the runway is in use.

The next step is to consider the percent time when the second priority runway can be used, looking only at the time intervals which have not already been assigned to the first priority runway. This usually results in a much smaller percent of time for second priority runway use. Continuing the process, still smaller times or zero times are assigned to the third and fourth priority runways.

It should also be noted that if the first or other priority runway cannot take all of the aircraft using the airport, the priority assignments must be limited to those aircraft which can use the priority runway. However, the problem of reassignment from the priority runway was rarely encountered in this study.

Curved Flight Tracks

In many cases, it is possible for the aircraft to turn away from densely populated areas and thereby significantly reduce the total number of people impacted by aircraft noise at a given level. Curved ground tracks have been used in conjunction with priority runways developed on the basis of visual inspection of the Geological Survey Maps mentioned above. Turns are made only at altitudes and airspeeds greater than 500 feet and v_2 10 and at bank angles no greater than 15^0 as recommended by the FAA in their Advisory Circular 91-50 (Reference 13). The radius of the turn is calculated using the formula:

$$R = v^2/g \tan$$

where: v = aircraft flight speed
g = acceleration of gravity
= angle of bank.

As an example, an aircraft with an altitude of 500 feet or more and at a $v_2 + 10$ speed of 145 knots could make a turn with a radius as small as 7000 feet.

AIRPORT DATA BASE ANALYSIS

In addition to the AIF variables identified previously, 16 additional variables were calculated for the data base by transforming the original variables. The new variables thus created are given in the following list:

- Log of the total population at 5 miles and 10 miles
- Log of the number of households at 5 miles and 10 miles
- Log of the total number of incomes at 5 miles and 10 miles
- Log of the total number of homes at 5 miles and 10 miles

- Log of the total number of renters at 5 miles and 10 miles
- Log of the total number of departures per year
- Log of the number of scheduled jet operations per 24-hour period (from AAS)
- Log of the number of 4-engine narrow body operations during the time period from 0700 to 2159
- Log of the number of 4-engine wide body operations during the time period from 0700 to 2159
- Square root of the airport area
- Number of scheduled jet operations per 24-hour period divided by practical daily operations capacity (airport utilization).

These variables were added because some transformation of a variable will frequently bear a closer relation to a criterion than the original variable.

At this point the data base contained 236 airports with measurements on 56 variables for each airport. An obvious first question concerning the data base is: What are the interrelationships among these variables? The data base contained 56 variables, but undoubtedly some of them were so highly correlated with each other that only relatively few sources of variation are represented by them.

The procedure chosen to approach this problem was "factor analysis". Factor analysis basically takes a matrix of the correlations of each variable with every other variable and resolves it into independent factors that comprise the variables in the matrix. A number of +1.0 through -1.0 is calculated for each variable with respect to each factor. This number is referred to as the loading of the variable on the factor.

In this study, factor analysis was used as an aid to making more informed choices concerning which variables to use in deciding how many categories the airports should be segregated into and in deciding which airports should go into which categories. Used in this fashion, factor analysis provided a rough guide for winnowing the variables down to a reasonable number to work with and for choosing variables that showed the most promise for making useful discriminations among airports.

The number of factors was increased from one through ten in one-factor steps to explore how the variables grouped with each successive increase in the number of factors An excerpt from a typical result is shown in Table 3.4 to provide an idea of how the variables grouped themselves.

The results shown in Table 3.4 may be interpreted in the following way. Factor 1 could be described as related to the total acoustic energy produced by airport operations. Factor 2 appears to be related to demographic features (number of people) of the area surrounding the airport. Factor 3 appears to be related to economic aspects (amount of money) of the area surrounding the airport. Factor 4 appears to be related to the activity of the airport. Factor 5 appears to be related to the average acoustic energy emitted by airport operations, and Factor 6 is evidently related to the growth of the area.

A relatively small number of variables was picked from the original set for use in determining airport categories. The reduced set of variables included the following:

- Jet operations day-night
- Log jet operations day-night
- Departures
- Log departures
- Number of IFR runways
- Total population at five miles
- Total population at ten miles
- Households in 1975 at five miles
- Households in 1975 at ten miles
- Average income at five miles
- Average home value at five miles

TABLE 3-4

EXAMPLE GROUPS OF VARIABLES RESULTING FROM FACTOR ANALYSIS

FACTOR Variable	1	2	3	4	5	6
Log departure	0.88	*	*	*	*	*
Mean ANI	0.88	*	*	*	*	*
Log jetops day night	0.82	*	*	*	*	*
Total rents ten mi	*	0.96	*	*	*	*
Total incoms five mi	*	0.96	*	*	*	*
Households 75 five mi	*	0.96	*	*	*	*
Total pop five mi	*	0.96	*	*	*	*
Households 75 ten mi	*	0.93	*	*	*	*
Total pop ten mi	*	0.922	*	*	*	*
Pop change ten mi	*	0.88	*	*	*	*
Average income five mi	*	*	0.89	*	*	*
Average home val five mi	*	*	0.86	*	*	*
Average home val ten mi	*	*	0.83	*	*	*
Log total pop five mi	*	*	0.83	*	*	*
Average rent five mi	*	*	0.83	*	*	*
Log households 75 five mi	*	*	0.82	*	*	*

* $r < 0.50$

TABLE 3-4 (Cont.)

Factor / Variable	1	2	3	4	5	6
Average rent ten mi	*	*	0.82	*	*	*
Jet ops day night	*	*	*	0.73	*	*
Departures	*	*	*	0.70	*	*
Mean FNL	*	*	*	*	0.82	*
Growth at five miles	*	*	*	*	*	0.81
Growth at ten miles	*	*	*	*	*	0.72

- Growth at five miles
- Mean ANI
- Mean FNL.

These variables appeared to represent a reasonable sample of the characteristics of airports and the areas surrounding them because the important aspects of the process of noise generation by the airport and the important aspects of the residential area surrounding the airport were represented in the data. Jet operations, day-night departures, and number of IFR runways are related to one aspect of noise generation (airport activity). Mean FNL is related to the noise characteristics of the fleet using the airport, and mean ANI, log departures, and log jet operations represent a mixture of airport activity and fleet characteristics. Total population at five and ten miles, and number of households in 1975 at five and ten miles are related to noise exposure, and average income at five miles and average home values at five miles are related to the wealth of the exposed population. Growth at five miles is probably related to both impacted population and its wealth.

REPRESENTATIVE AIRPORT CATEGORY SELECTION

With the number of variables reduced to a manageable number, the approach taken to segregate airports into categories was to use different combinations of variables and number of categories until something approaching an optimal combination of categories and variables appeared to be achieved.

The technique used for determining the number of categories and assigning airports to them was the "K-means algorithm" (Reference 9). The optimal combination was the use of six categories with the airports assigned by seven variables. The variables were:

- Total population at five miles
- Households in 1975 at ten miles
- Average income value at five miles
- Departures
- Mean FNL
- Mean ANI
- Log jet operations day-night.

Many different combinations of variables and categories were tested and compared, and several criteria were used in evaluating them. Discussion of the process of arriving at the final categorization follows.

Internal Consistency

Internal consistency was the primary criterion of evaluating the results of a particular combination of variables and categories. This was approached in two ways. First, plots of the location of airports with respect to the categories were examined. The plot of the final categorization is shown in Figure 3.2. The figure shows the multivariate distance* of each airport from the means of its own category with respect to every other category projected on a plane that passes through the centers of three categories. Combinations that result in plots showing lesser amounts of overlap among categories were considered to be more internally consistent. In other words, relatively simple lines could be drawn in Figure 3.2 that would separate each category from all others.

Another measure of internal consistency involved ranking the categories with respect to the variables. Each category of airport has a mean value of all of the variables used in the analysis. The categories were ranked with respect to each variable, and a sum and mean of ranks was found. This information is shown for the final categorization in Table 3.5, and, again, it shows a consistent relationship among the categories.

Qualitative Considerations

Another criterion, which was less quantitatively defined but of no less importance in evaluating the variables that went into the categorization process, was relevance to the aim of the project to produce noise exposure estimates. Thus, when the list of variables in Table 3.5 is examined, a rough

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*This distance is the positive square root of the sum of the squared distances from the centers of the category (the means of all seven variables for that category) to the airport (the observed values on all seven variables for that airport).

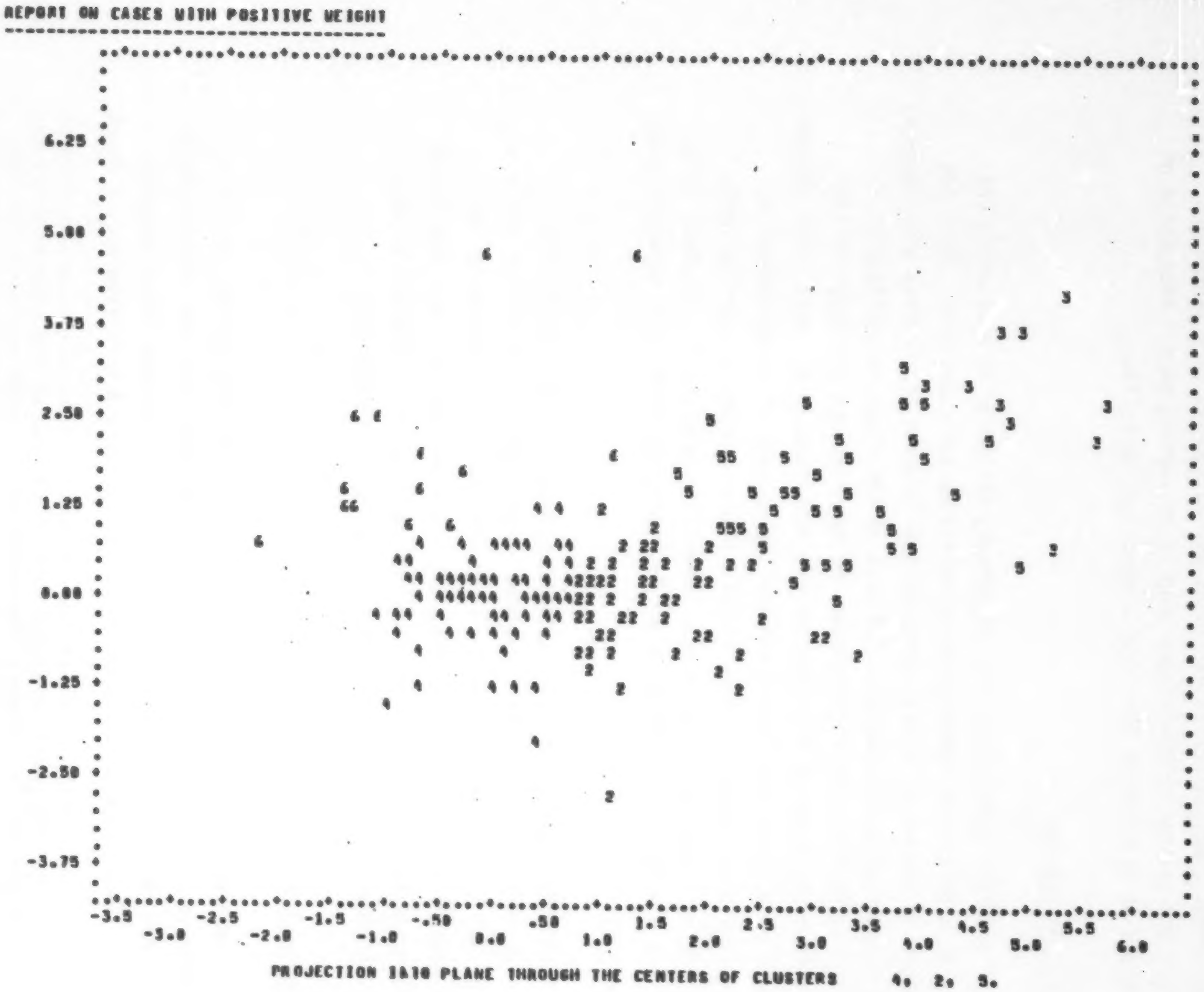

FIGURE 3.2. GROUPING OF AIRPORTS IN FIVE* CATEGORIES

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*Category 1 contained only one airport and is not shown here.

TABLE 3-5

RANK OF AIRPORT CATEGORIES ON THE SIX VARIABLES USED IN THE FINAL CLASSIFICATION

CATEGORY VARIABLE	1	2	3	4	5	6
Total population at five miles	2	1	3	4	6	5
Number of households in 1975 at ten miles	2	1	3	4	5	6
Average home value at five miles	2	1	4	3	6	5
Number of departures	1	2	3	4	5	6
Mean FNL	1	6	2	4	3	5
Mean ANI	1	2	3	4	5	6
Log jet operators, day-night	1	2	3	4	5	6
Sum of ranks	10	15	21	27	36	38

sort of weighting can be seen in the number of each type of variable included in the final set. Two variables (population and households) represent the number of people around the airports, and another two variables (airport noise index and log of the jet operations) represent generated noise weighted by the activity of the airport. Four of the seven variables, then, represent the most important aspects of noise exposure. The inclusion of departures gives some weighting to airport activity alone, and FNL gives some weighting to an average noise level alone. Finally, the inclusion of average home value gives some weighting to the value of the property in the exposed area.

Sensitivity to Changes

Although this was not of major importance, some consideration was given to the effects changing the variables and the number of categories.

Variables. Minor changes in the variables produced little or no change in the categories. For example, it made no difference whether population at five or ten miles were included; either one gave the same results. Growth was not included in the final set of variables because it appeared to have no effect on the categorization.

Number of Categories. If more than six categories were used, no change was seen in the categories whose members included the larger airports. The only effect seen was to divide the categories containing the smaller airports into smaller and smaller categories as the number of categories was increased. There seemed to be little value in making fine discriminations between airports that constitute a relatively insignificant part of the airport noise problem.

RPORT DETERMINATION

The preceding discussion, although important in its own right in some respects, is merely prologue to the actual determination of Rports to represent categories of airports.

A total of 71 airports were selected from the 236 airports and six (6) airport categories for ALAMO computer runs. The airports selected from each category were those airports identified as being closest to the category cluster mean*, except for categories A and B, in which all of the airports were analyzed. The percentage of airports selected from each Rports category (for ALAMO runs) was based on the relative percentage of total annual (1979) aircraft operations and the average surrounding airport population associated with each Rports category. That is, a larger percentage of the airports in airport categories A and C were selected for ALAMO runs as compared with the percentage of airports selected from categories D, E, and F.** This selection criterion appeared reasonable since it was expected that the major proportion of the national noise exposure would be due to aircraft operations at those airports included in categories A to C.

The distribution of the 71 airports by Rport category is presented in the following table.

Distribution by Rport Category

Rport Category	Number of Airports in the Category	Number of Airports Selected for ALAMO Runs
A	13	13
B	1	1
C	44	21
D	71	20
E	15	6
F	92	10
TOTAL	236	71

Methodology Used to Select Rports

Airport community noise impact reports were generated for most of the 71 airports. However, for five (5) of the airports in airport category E, no demographic data were reported. For many of the other 66 airports, no demographics were reported for entire octants or some of the L_{dn} contour bands.

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* Airport category B contained only one airport, La Guardia.

**To be more precise, the airports ranked by the multivariate sum of squared deviations from all of the category means. The airports with the lowest multivariate sums of squares were selected.

The ALAMO noise impact reports for each of the 66 airports were used to determine the contour areas and the population enclosed within equal noise level bands of L_{dn} 65 dB to 75 dB and L_{dn}75 and greater. The mean and the corresponding standard deviation of the areas and the population for these two noise contour bands were determined for each of the Rport categories using data for the individual airports in that Rport category.

The Rport selected to represent each airport was determined by comparing contour band values for area and population for each airport in the category with the Rport category limits, defined as the contour band mean plus or minus a fixed percentage of the standard deviation. The fixed percentage of the standard deviation was adjusted until all of the contour band values for one airport fell within the band limits. This airport was designated the Rport for the category considered. As an example of the Rport selection procedure, Table 3.6 presents a listing of the data used to determine the Rport representing Rport category A. The fixed percentage of the contour band standard deviation used in the Rport category A analysis was 50 percent.

Since many of the airports in Rport categories D, E, and F had no population within the 65 dB to 75 dB and 75 dB and greater contour bands, the selection of the Rports for these categories could not be made in accordance with the above procedures. After examining the noise impact data for the airports included in these airport categories, it was decided to omit categories E and F. The Rport representing category D was selected using a similar, but somewhat modified, procedure as that used to select Rport for categories A and C. The following table identifies the Rport representing each of the four (4) Rport categories:

TABLE 3-6
RPORT DETERMINATION ANALYSIS: AIRPORT CATEGORY A

APT ID	ALAMO OUTPUT			
	AREA SQ. MI.		POPULATION (PEOPLE)	
	65 to 75 dB	75 + dB	65 to 75 dB	75 + dB
MIA	30.91	8.15	134011	7568
BOS	26.57	6.07	203359	9341
DEN	29.34	7.58	88029	6988
STL	25.62	5.45	93346	11664
LAX	40.66	11.34	204978	28859
PHL	22.63	4.86	71556	2734
SFO	33.10	7.65	58022	13802
DFW	49.22	11.19	18250	0
DCA	22.68	4.93	202464	3817
EWR	19.62	4.54	120782	5277
ORD	58.44	14.29	277801	10941
ATL	65.98	16.15	44902	32389
JFK	27.98	6.85	219940	6709
MEAN	34.83	8.39	133649	10776
σ (N-1)	14.56	3.75	80389	9604
MEAN +0.50σ	42.11	10.27	173844	15578
MEAN -0.50σ	27.55	6.52	93454	5974

Rport Category	Selected Rport
A	Miami, FL (MIA)
B	La Guardia, NY (LGA)
C	San Antonio, TX (SAT)
D	Sioux Falls, SD (FSD)

A complete listing of the 236 airports contained in the combined airport/aircraft data base is presented by Rport category in Table 3.7. The 71 airports selected for ALAMO runs are denoted by a single *; Rports are denoted by a double *.

TABLE 3.7

DISTRIBUTION OF AIRPORTS BY RPORT CATEGORY

Rport Category	APT ID.	Location
A	ATL	Atlanta, GA*
	DFW	Dallas, TX*
	LAX	Los Angles, CA*
	ORD	Chicago, Il*
	DEN	Denver, CO*
	JFK	New York, NY*
	SFO	San Francisco, CA*
	EWR	Newark, NJ*
	BOS	Boston, MA*
	DCA	Washington, DC*
	MIA	Miami, FL**
	STL	St. Louis, MO*
	PHL	Philadelphia, PA*
B	LGA	New York, NY**
C	BDL	Windsor Lock, CT*
	BNA	Nashville, TN*
	BUF	Buffalo, NY
	BWI	Baltimore, MD*
	CLE	Cleveland, OH
	CLT	Charlotte, NC
	CVG	Cincinnati, KY*
	DAY	Dayton, OH*
	DTW	Detroit, MI
	ELP	El Paso, TX
	FLL	Ft. Lauderdale, FL*
	HNL	Honolulu, HI
	IAD	Washington, DC
	IAH	Houston, TX
	IND	Indianapolis, IN*
C	JAX	Jacksonville, FL
	LAS	Las Vegas, NV
	MCI	Kansas City, MO
	MCO	Orlando, FL*
	MEM	Memphis, TN*
	MKE	Milwaukee, WI
	MSP	Minneapolis, MN
	MSY	New Orleans, LA*
	OAK	Oakland, CA
	OKC	Oklahoma City, OK*
	OMA	Omaha, NB
	PBI	West Palm Beach, FL*
	PDX	Portland, OR*
	PHX	Phoenix, AZ
	PIT	Pittsburgh, PA
	RNO	Reno, NV
	SAN	San Diego, CA
	SAT	San Antonio, TX**
	SDF	Louisville, KY
	SEA	Seattle, WA*
	SJC	San Jose, CA
	SLC	Salt Lake City
	SMF	Sacramento, CA
	SYR	Syracuse, NY*
	TPA	Tampa, FL*
	TUL	Tulsa, OK*
	TUS	Tucson, AZ*
	ABQ	Albuquerque, NM*
	ANC	Anchorage, AK
D	ALB	Albany, NY
	BTV	Bulrington, VT
	BUR	Burgank, CA
	CAK	Akron, OH
	CMI	Champaign/URB, IL
	DAL	Dallas, TX
	FAI	Fairbanks, AK
	GRR	Grand Rapids, MI
	GSO	Greensboro, NC
	HPN	White Plains, NY
	ITO	Hild, HI
	JAN	Jackson, MS*
	JNU	Juneau, AK
	KTN	Ketchikan, AK
	LEX	Lexington, KY*
	LGE	Long Beach, CA
	LIH	Lihue, HI
	MDW	Chicao, IL
	MSN	Madison, WI*
	OGG	Kahului, HI
	PSP	Palm Springs, CA
	SBA	Santa Barbara, CA
	SNA	Santa Ana, CA
	AUS	Austin, TX
	MLI	Moline, IL*
	MOB	Mobile, AL
	PVD	Providence, RI
	DSM	Des Moines, IA*
	HOU	Houston, TX
D	LAN	Lansing, MI*
	BIL	Billings, MI*
	CRW	Charleston, SC
	BIS	Bismark, ND
	BOI	Boise, ID*
	FAR	Fargo, ND
	GRB	Green Bay, WI
	COS	Colorado Springs, CO*
	SRQ	Sarasota, FL*
	CAE	Columbia, SC
	ICT	Wichita, KS
	SHV	Shreveport, LA
	TOL	Toledo, OH*
	FMY	Ft. Meyers, FL
	GEG	Spokane, WA
	LIT	Little Rock, AR
	RIC	Richmond, VA
	MBS	Saginaw, MIB
	TRI	Bristol, TN*
	BTR	Baton Rouge, LA
	CID	Cedar Rapids, IA*
	EUG	Eugene, OR*
	RDU	Raleigh-Durham, NC
	ROA	Roanoke, VA
	TYS	Knoxville, TN
	ABE	Allentown, PA

*Denotes airports selected for ALAMO computer runs

**Denotes Rport

TABLE 3.7 (Cont.)

DISTRIBUTION OF AIRPORTS BY RPORT CATEGORY

Rport Category	APT ID.	Location
D	CHA	Chattanooga, TN
	DAB	Daytona Beach, FL
	FSD	Sioux, Falls, SD**
	ONT	Ontario, CA
	PWM	Portland, ME*
	BHM	Birmingham, AL
	FAY	Fayetteville, NC*
	GTF	Great Falls, MT
	AVL	Ashville, NC
	FNT	Flint, MI
	PIA	Peoria, IL
	TLH	Tallahassee, FL
	ORF	Norfolk, VA
	ROC	Rochester, NY
	ADQ	Kodiak, AK
	ESF	Alexandria, LA
	GFK	Grand Forks, ND
	GLH	Greenville, MS*
	KOA	Kona Ke Ahole Kailua-Kora, HI
	MSO	Missoula, MT*
	OME	Nome, AK
	OTZ	Kotzebue, AK*
	PIH	Pocatello, ID*
	RPA	Rapid City, SD*
	SJT	San Angelo, TX*
	STT	Charlotte Amalie, VI
	STX	Christiansted, VI
	SAV.	Savannah, GA
	SJU	San Juan, PR
F	ISO	Kinston, NC
	JLN	Joplin, MO
	LAW	Lawton, OK
	LCH	Lake Charles, LA
	LFT	Lafayette, LA
	LMT	Klamath Falls, OR
	LNK	Lincoln, NE
	LSE	La Crosse, WI
	LWB	Lewisburg, WV
	LWS	Lewiston, ID
	MAF	Midland, TX
	MCN	Macon, GA*
	MFE	McAllen, TX
	MFR	Medford, OR
	MGM	Montgomery, AL
	MKG	Muskegon, MI
	MKK	Kaunakakai, HI
	MLB	Melbourne, FL
	MLU	Monroe, LA
	MOT	Minot, ND
	MQT	Marquette, MI
	OSH	Oshkosh, WI*
	PFN	Panama City, FL
	PIR	Pierre, SD*
	PKB	Parkersburg, WV
	PNS	Pensacola, FL
	PSC	Pasco, WA*
	PUB	Pueblo, CO
	RDD	Redding, CA
	RFD	Rockford, IL
	RHI	Rhinelander, WI
F	RST	Rochester, MN
	SBN	South Bend, IN
	SCK	Stockton, CA
	SLN	Salina, KS
	SPI	Springfield, IL
	ABY	Albany, GA*
	ACV	Arcata-Eureka, CA
	AGS	Agusta, GA
	ALO	Waterloo, IA*
	AVP	Wilkes-Barre, PA
	AZO	Kalamazoo, MI
	BGM	Binghampton, NY
	BGR	Bangor, ME
	BPT	Beaumont, TX
	BTM	Butte, MT
	BZN	Bozeman, MT
	COU	Columbia, MO
	CPR	Caspar, WY
	CSG	Columbus, GA
	DEC	Decatur, IL*
	DLH	Duluth, MN
	ELM	Elmira, NY
	ERI	Erie, PA
	ESC	Escanaba, MI
	EVV	Evansville, IN
	FLO	Florence City, SC
	FOE	Topeka, KS
	FSM	Ft. Smith, AR
	FWA	Ft. Wayne, IN
	GJT	Grand Junction, CO
	GNV	Gainsville, FL
F	GPT	Bulfort, MS*
	HIB	Hibbing, MN
	HLN	Helena, MT
	HRL	Harlingen, TX
	HSV	Huntsville, AL
	HTS	Huntington, WV*
	IDA	Idaho Falls, ID
	ILN	Iron Mountain, MI
	INT	Winston-Salem, NC
	SUX	Sioux City, IA
	TCL	Tuscaloosa, AL
	TVC	Traverse City, MI
	VLD	Valdosta, GA
	VPS	Valparaiso, FL
	YKM	Yakima, WA*
	ABI	Abilene, TX
	CHO	Charlottesville, VA
	PHF	Newport News, VA
	LBB	Lubbock, TX
	SGF	Springfield, MO
	MEI	Meridian, MS
	SIT	Sitka, AK
	DHN	Dothan, AL
	YNG	Youngstown, OH
	CRP	Corpus Christi, TX
	GTR	Columhus, MS
	AMA	Amarillo, TX
	ISP	Islip
	ITH	Ithaca, NY

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IV. PROGRAM SCENARIO DEVELOPMENT

The benefits and costs associated with implementation of an airport noise soundproofing and relocation effort will vary depending on the assumptions employed regarding program content, eligibility, timing and funding. Practical implications of these assumptions are discussed in Chapter II. To quantify these benefits and costs on both an airport-specific and national basis, a methodology was developed which enabled an assessment of how noise impacts might change as program assumptions change. The culmination of the methodology was the development of a series of program scenarios which was used to assess:

- Changes in noise impacts associated with advances in aircraft source noise reduction

- Impacts of airport-environs land use controls as a means to minimize program costs and noise exposure impacts

- Trade-offs available from soundproofing residences which might otherwise be candidates for relocation

- Implications of additional airport noise reduction alternatives involving preferential runway use, flight tracks and flight procedures.

This chapter presents an overview of the scenario development methodology. Chapter V describes the program scenarios and provides program cost summaries.

GENERAL ASSUMPTIONS

The keystone of this analysis was the assumption that aviation noise is a serious problem at many of the Nation's commercial airports and that a concerted program of soundproofing and relocating private residences exposed to excessive airport noise levels is needed to address residual impacts. Residual impacts are defined as those remaining after reasonable noise control alternatives (such as alternate flight procedures, preferential runway use, etc.) are implemented.

Other general assumptions guiding scenario development were:

- All private residences within within specified noise contours (i.e., L_{dn} 65 to 75 dB and, as an option, L_{dn} 65 to 80 dB) will be candidates for soundproofing assistance.
- All private residences within other higher specified noise contours (i.e., L_{dn} 75+ or 80+ dB) will be candidates for relocation assistance.
- The program should apply to residences exposed to specified noise contours projected for the year 2000.
- The concept of representative airports, or "Rports", will be used to assess program issues and costs which might be faced by real airports.

The concept and derivation of a representative airport, instead of a pseudo-airport as used in some earlier studies, was explained in more detail in Chapter III. The use of representative airports enabled generation of fleet composition, program costing and other variables representative of the characteristics of real air carrier operations and the actual composition of communities affected by aircraft noise. However, it bears emphasis here that the analysis of a representative airport is not a substitute for noise compatibility planning which must be undertaken by an actual airport. The reason is that it was not possible in the study methodology to incorporate the unique features of demographic and aircraft operational patterns extant at the airport. Rather, general patterns were employed to in essence bound the problems which may arise in planning for a comprehensive relocation and soundproofing program.

FLEET FORECASTS

Concern over fuel efficiency and noise levels, coupled with advances in aeronautical technology, have lead to a changing mix of the Nation's air carrier fleet. Through the 1970's, the less fuel-efficient and noisier aircraft were gradually being replaced by new aircraft types which placed a premium on fuel economy and quieted engines. This pattern will continue into the future as older aircraft are retired from service and as new aircraft types are introduced into the market. The projected mix and number of aircraft operations in selected forecast years will have a direct bearing on the level of airport community noise exposure. Accordingly, the fleet mix was forecast for the years 1990, 2000 and 2030* in the aggregate and then for the four designated Rports. Baseline 1979 data were also developed for comparison purposes.

National Air Carrier Fleet Composition

The national air carrier fleet in 1979 consisted of 2,384 aircraft covering some 30 aircraft types (Reference 1). Aircraft types are grouped in Table 4.1 according to seven engine/body designations as follows:

- 2-engine, low by-pass ratio engine, narrow body (2LN)
- 3-engine, low by-pass ratio engine, narrow body (3LN)
- 4-engine, low by-pass ratio engine, narrow body (4LN)

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*The forecast for the year 2030 is essentially a forecast for some date in the future when all aircraft in the air carrier fleet will meet FAR Part 36, Stage 3 noise limits.

TABLE 4.1
BASELINE 1979 AIRCRAFT FLEET

ENGINE/ BODY DESIGNATION	AIRCRAFT NAME	DEPART- URES (1,000's)	NO. OF AIRCRAFT (BY TYPE)	APF[b]	NO. OF AIRCRAFT (BY SERIES)
2LN	737 W/SAM	515.3	206	2501	206
	DC-9-15	250.1	381	3062	82
	DC-9-32	750.1			245
	DC-9 W/SAM	166.5			54
	BAC-111	104.2	28	3721	28
	DC-9-80[a]	-	-	2920	-
3LN	727-100	697.6	1029	2060	339
	727 W/SAM	711.2			345
	727 ADV W/SAM	711.2			345
4LN	707-120/320	2.4	175	1154	2
	707-120B	100.9			87
	707-320 B/C	98.6			86
	720 B	7.7	7	1100	7
	DC-8-3C	3.6	188	709	5
	DC-8-55	40.6			57
	DC-8-61/63	89.1			126
2HW	A-300	12.0	12	1000	12
	A-310[a]	-	-	1825	-
	B-767[a]	-	-	1825	-
3HW	DC-10-10	95.4	140	899	106
	DC-10-30	3.1			3
	STRETCH	27.4			31
	L-1011	122.4	87	1407	87
4HW	747-100	83.1	131	734	113
	747 STR	7.9			11
	747-200	5.2			7
	B-747 TYPE[a]	-	-	730	-
2HN	B-737-300[a]	-	-	2920	-
	B-757[a]	-	-	1825	-
TOTAL		4,605.6	2,384	1932	2,384

[a] DENOTES new aircraft type after 1979.

[b] Aircraft Productivity Factor (APF) = Departures ÷ Number of Aircraft.

- 2-engine, high by-pass ratio engine, wide body (2HW)
- 3-engine, high by-pass ratio engine, wide body (3HW)
- 4-engine, high by-pass ratio engine, wide body (4HW)
- 2-engine, high by-pass ratio engine, narrow body (2HN).

Available data on fleet composition was limited to general aircraft types and did not identify multiple series for any given type. A finer distinction was necessary, however, to convert the data to a form acceptable as input to the Integrated Noise Model. That is, the aircraft series within a given type exhibit different noise curves which in turn affect noise level predictions.

The number of aircraft by type and series was determined by comparing departure data for each series with the total for all series. For example, the Boeing 727 has three distinct series as shown in Table 4.1. Departures for each series in 1979 (Reference 2) were 697,600 for the 727-100, 711,200 for the 727 W/SAM* and 711,200 for 727 ADV W/SAM. Total 727 departures were 2,120,000. An Aircraft Productivity Factor, or APF, was calculated by dividing total 727 departures by the total number of aircraft of this type. The APF for the 727 is thus 2,060. It was assumed that the APF for a given aircraft type was constant for all aircraft represented in the series. Accordingly, the number of aircraft by series was determined by dividing departures for each series by the composite Aircraft Productivity Factor (see Table 4.1).

Aircraft fleet projections for the selected forecast years of 1990 and 2000 were based on a 1.7 percent annual growth in total aircraft from 1979 (Reference 3). These projections, however, understate the expected growth of commercial aviation. As mentioned, the less fuel-efficient aircraft are being replaced by advanced series. In addition, the average number of seats per aircraft is increasing, resulting in fewer departures and fewer total aircraft required to meet any given demand level. This factor is depicted in Tables 4.2 and 4.3 which group the air carrier fleet according to nominal seat capacity. Table 4.2 shows that in 1979 aircraft with nominal seat capacities of 140 or less comprised almost 80 percent of the total air

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*Denotes advanced design incorporating sound absorbent material, or "SAM".

TABLE 4.2
AIR CARRIER FLEET COMPOSITION BY SEAT CAPACITY

Seat Category	No. of (Avg) Seats	Aircraft Name	Number of Aircraft		
			1979	1990	2000
100	115	DC-9-32	245	112	-
	90	DC-9-15	82	38	-
	97	BAC-111	28	-	-
	94	727-100	339	-	-
	115	737 W/SAM	206	108	-
		Sub-Total	900	258	-
140	148	707-320 B/C	86	-	-
	125	707-120 B	87	-	-
	167	720-B	7	-	-
	153	DC-8-55	57	-	-
	149	707-120/320	2	-	-
	146	DC-8-30	5	-	-
	139	DC-9 W/SAM	54	41	-
	145	727 W/SAM	345	260	-
	145	727 ADV W/SAM	345	261	-
	167	DC-9-80[a]	-	100	240
	124	B-737-300[a]	-	84	100
		Sub-Total	988	746	340
200	224	DC-8-61/63	126	-	-
	235	A-310[a]	-	232	300
	233	B-767[a]	-	233	300
	187	B-757[a]	-	167	215
		Sub-Total	126	632	815
280	275	A-300	12	188	200
	315	DC-10-10	106	94	100
	280	L-1011	87	191	203
	315	DC-10-30	3	189	200
	315	STRETCH	31	170	180
		Subtotal	239	832	883
380	452	747-200	7	200	883
	452	747-100	113	87	-
		Subtotal	120	237	883
550	496	747 STRETCH	11	115	340
750	743	B-747 Type[a]	-	-	136
	TOTAL		2384	2870	3397

[a] Denotes new aircraft type after 1979.

TABLE 4.3
AIR CARRIER FLEET CAPACITY BY SEAT CAPACITY

Seat Category	No. of Aircraft			Total Seat Capacity (1,000's)		
	1979	1990	2000	1979	1990	2000
100	900	258	-	90.0	258.8	-
140	988	746	340	138.3	104.4	47.6
200	126	632	815	25.2	126.4	163.0
280	239	832	883	66.9	233.0	247.2
380	120	287	883	45.6	109.1	335.5
550	11	115	340	6.0	63.2	187.0
750	-	-	136	-	-	102.0
TOTAL	2384	2870	3397	372.0	661.9	1082.3
Average Seats/ Aircraft	-	-	-	156	231	319

carrier fleet. By 1990, however, the percent composition drops to 35 percent as all of the 707's and many of the existing 727, 737 and DC-9 aircraft are retired and replaced by higher capacity aircraft. Conversely, the market share of aircraft with seat capacities of 380 or greater grows from 6 percent in 1979 to 14 and 40 percent in years 1990 and 2000, respectively. Total seat capacity increases from 372,000 in 1979 to 1,082,000 in year 2000 as the average number of seats per aircraft increases from 156 to 319 during the period (see Table 4.3).

While the total seat capacity increases dramatically during the forecast period, total departures show a modest growth and, in fact, decrease from year 1990 to year 2000 (see Table 4.4). As the fleet mix changes over time to emphasize aircraft with higher capacities, departures per aircraft (defined by the APF) decline. For example, the composite Aircraft Productivity Factor of 1,932 in 1979 decreases to 1,664 and 1,293 in the two forecast years, respectively.

Representative Airport Fleet Projections

The next step in the projection methodology involved projecting air carrier activity by each of the four Rport categories and then by specific Rport. Total fleet departures were determined based on the number of aircraft times the applicable APF. Next, departures for each Rport category were determined by summing the departures for each airport contained within the Rport category (Reference 2). Airports contained in the four Rport categories comprised 62 percent of national air carrier departures in baseline year 1979. This same percentage was then applied to total departures for each of the three forecast years to derive total Rport departures.

Total departures next had to be allocated to each of the Rport categories. This was done by a subjective adjustment of the baseline 1979 departure data. Allocation of Rport category departures to the seven seat category groupings (see Tabler 42) was similarly performed on a judgemental basis. Consideration here was given to the general nature of airport operations (e.g., hub versus terminal) and the type and mix of aircraft which might be handled by each airport given certain operational constraints (e.g., adequate runway length to accommodate wide-bodied jets).

Since each Rport is representative of all airports within the respective category, departures for each Rport were then determined by dividing category departures (by seat classification) by the total number of airports in that category.

The results of this procedure are summarized in Table 4.4. A final step involved allocating total departures for each representative airport by seat category and then by specific aircraft type or series. Details on the procedures are provided in Reference 4.

Noise Source Regulation

As a general rule, control of noise at the source (the aircraft) is more cost-effective than trying to protect people from an excessively noisy source at each location where it operates. In 1969, the Federal Aviation Administration took a major step in this direction by issuing a new Federal Aviation Regulation Part 36 (FAR 36) requiring that new design aircraft be certificated to meet specific noise levels. These 1969 noise standards came to be known as Stage 2 levels. The unregulated aircraft in operation prior to 1969 were designated Stage 1 (Reference 5).

Although FAR 36 was an excellent first step in aircraft noise regulation, it was understood by both the FAA and the industry that there remained many other problems to be resolved. The 1969 rule applied only to new design aircraft; that is, those whose application for initial certification was submitted earlier than the 1969 date which was specified in the rule. This left the manufacturer of older design aircraft unregulated, as well as the operation of the older design aircraft. Thus, it was not surprising that, in 1973, the U.S. jet-powered carrier fleet of approximately 2,000 aircraft consisted of more than 90 percent older design aircraft which did not meet, and were not required to meet, the Stage 2 noise levels. Furthermore, due to the long structural and economic life of these aircraft, they would probably remain in the fleet for 10 to 20 years or more as a significant factor in the airport noise problem.

Since 1973 the FAA has taken steps to fill these gaps. The FAA has issued a rule which requires that new production of older design aircraft

TABLE 4.4

ANNUAL DEPARTURES BY RPORT CATEGORY
(Thousands)

Rport/Rport Category	BASELINE	FORECAST YEAR	
	1979	1990	2000
Miami, Fl.			
Category Departures	1234	1249	1112
Percent[a]	43.2	42.0	41.0
Rport Departures	94.9	96.0	85.6
NYC (La Guardia)			
Category Departures	111	118	109
Percent[a]	3.9	4.0	4.0
Rport Departures	111.0	118.0	109.0
San Antonio, Tx.			
Category Departures	1156	1224	1139
Percent[a]	40.5	41.2	42.0
Rport Departures	26.3	27.8	25.9
Sioux Falls, SD			
Category Departures	355	380	353
Percent[a]	12.4	12.8	13.0
Rport Departures	5.0	5.4	5.0
Total Category Departures	2856	2971	2713
Total National Departures	4606	4777	4394

[a] Percent of total category departures.

comply with the Stage 2 noise levels (Reference 6). In addition, in December 1976 the FAA set forth a phased compliance schedule by which all aircraft in the U.S. fleet, not engaged in foreign commerce, are to be brought into compliance with Stage 2 noise levels no matter when they were designed or manufactured (Reference 7). Finally because the Stage 2 noise levels were no longer sufficiently stringent for new-design aircraft, the FAA has further reduced the permissible noise levels for them (Stage 3).

The FAA rule for new production of older design aircraft (Reference 7) was effective on December 31, 1974. It brought under the Stage 2 limits the manufacturing of all turbojet subsonic aircraft which were of designs certificated before 1969. This represented the bulk of the aircraft being manufactured at that time, and therefore significantly increased the number of aircraft subject to the FAR 36 noise requirements.

The pace of compliance with FAR 36, Stage 2 has accelerated over the past years, and will continue into the future. For example, 21 percent of the air carrier fleet was in compliance at the beginning of 1977, and 42 percent was expected to be in compliance by mid-1980. About 86 percent of the U.S. fleet is expected to be in compliance by 1985 (Reference 8).

While the compliance statistics are impressive, the benefits of the advanced technologies embodied in the Stage 3 requirements will not accrue for some time. There tends to be a 7 to 10 year delay between the demonstration of a new technology and its introduction into new designs for fleet use. Then an additional 10 or more years go by before these quieter aircraft make up a substantial portion of the fleet so that they make a noticeable impact on airport-community noise exposure. Thus, the second generation of quieted aircraft (e.g., B-757 and B-767) using the Stage 3 technology developed in the 1970's is being produced for service in the 1980's and will begin to impact exposed communities in the 1990's. Noise levels associated with stages 2 aNd 3 are presented in Table 4.5.

TABLE 4.5
FAR-36 NOISE LEVELS BY STAGE[a]

Seat Category	No. Engines	(TAKE-OFF LEVELS (EPNdB)		(APPROACH LEVELS (EPNdB)	
		Stage 2	Stage 3	Stage 2	Stage 3
100	2	97.9	90.9	103.9	100.2
	3		39.9		
	4		95.9		
140	2	100.3	92.8	104.9	101.3
	3		95.8		
	4		97.8		
200	2	102.8	94.8	105.9	102.5
	3		97.8		
	4		99.8		
280	2	105.3	96.8	106.9	103.6
	3		99.8		
	4		101.8		
380	2	107.5	98.6	107.8	104.7
	3		101.6		
	4		103.6		
550	2	108.0	100.7	108.0	105.0
	3		103.7		
	4		105.7		
750	2	108.0	101.0	108.0	105.0
	3		104.0		
	4		106.0		

[a] Source: Reference 9.

DEMOGRAPHIC FORECASTS

Four general exposure parameters are defined to compare scenario results. These are population, residences, area and program costs for the soundproofing and for the relocation aspects of the total program. The parameters are quantified primarily using selected output from NASA's Airport Noise-Levels and Annoyance Model, or ALAMO (Reference 10).

ALAMO contains a large demographic data base management program developed by CACI, Inc., and called SITE II. Using the SITE II data base, airport-specific Demographic Profile Reports are generated by the ALAMO program for each noise level contour band (L_{dn} as follows: 55-60, 60-65, 65-70, 75-80, 80-85, 85+, 65-75 and 75+. A sample profile report is shown on Figure 4.1.

While the profile reports contain a wealth of valuable information, the data is primarily based on the 1970 census.* Changing economic and demographic conditions over the past 10 years, particularly with respect to items such as population, households, housing units and structures and housing and rental values may seriously erode the validity of using the direct ALAMO output to estimate relocation and soundproofing costs for 1979 and for selected forecast years. Accordingly, the procedure used to update selected demographic variables is described below.

Updating Procedure Framework

An important advantage of using the ALAMO data base for program costing and impact evaluation was that it presents discrete data for a given airport based on specific noise level contour bands based on specific assumptions regarding aircraft fleet mixes, total departures, flight procedures, runway use, etc. The SITE II data base mentioned previously contains demographic information by Census Tracts and each tract in turn is

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*More current data (generally 1977) is available for selected variables, namely total population, number of households and per capita income.

FIGURE 4.1

SAMPLE DEMOGRAPHIC PROFILE REPORT

```
                                                                  CONTOUR
MIAMI INTERNATIONAL
MIAMI, FLORIDA

                                      * * * * * * * * * * * * * * * * * * * *
                                      *                       LATEST    CHANGE
         DEG MIN SEC                  *                                 FROM 70
LATITUDE     25  47  40               * 1977 POPULATION       134011      -8037
LONGITUDE    80  17  17               * 1977 HOUSEHOLDS        54257       5696
                                      * 1977 PER CAP INCOME  $ 5181     $ 2261
LDN 65-75 DB                          *
                                      *   ANNUAL COMPOUND GROWTH    -.8
WEIGHTING PCT   100                   * * * * * * * * * * * * * * * * * * * *

                              1970 CENSUS DATA

POPULATION                     AGE AND SEX
TOTAL      142048  100.0                       MALE             FEMALE        TOTAL
WHITE      124205   87.4       0-5        5232    7.8        5273    7.0        7.4
NEGRO       17017   12.0       6-13       8509   12.7        8074   10.8       11.7
OTHER         826     .6       14-17      4225    6.3        3988    5.3        5.8
                               18-20      2703    4.0        3414    4.6        4.3
SPAN        77893   54.8       21-29      7689   11.5        8831   11.8       11.6
                               30-39      8522   12.7        9136   12.2       12.4
                               40-49      9359   14.0       10674   14.2       14.1
FAMILY INCOME (000)            50-64     12697   18.9       14582   19.4       19.2
$0-5        10458   29.0       65 +       8116   12.1       11022   14.7       13.5
$5-7         5960   16.5       TOTAL     67052              74994
$7-10        7863   21.8       MEDIAN(AGE)       36.1                38.7      37.4
$10-15       7533   20.9
$15-25       3399    9.4      HOME VALUE (000)            OCCUPATION
$25-50        737    2.0      $0-10       1739   11.4     MGR/PROF       8874   15.1
$50 +         102     .3      $10-15      4379   28.7     SALES          3936    6.7
TOTAL       36052             $15-20      5058   33.2     CLERICAL      11347   19.3
                              $20-25      2319   15.2     CRAFT          8167   13.9
AVERAGE   $ 8706              $25-35      1325    8.7     OPERTIVS      13382   22.7
MEDIAN    $ 7614              $35-50       290    1.9     LABORER        3048    5.2
                              $50 +        122     .8     FARM            185     .3
                               TOTAL     15232            SERVICE        8958   15.2
RENT                                                      PRIVATE         947    1.6
$0-100      13980   47.2      AVERAGE $17612
$100-150     9936   33.5      MEDIAN  $16481
$150-200     4334   14.6        OWNER   34.0              EDUCATION   ADULTS > 25
$200-250      819    2.8                                  0-8           39844   42.9
$250 +        551    1.9                                  9-11          13838   14.9
TOTAL       29620             AUTOMOBILES                 12            23594   25.4
                              NONE       11477   23.6     13-15          8328    9.0
AVERAGE     $ 107             ONE        25011   51.5     16 +           7285    7.8
MEDIAN      $ 104             TWO         9977   20.5
  RENTER     66.0             THREE+      2088    4.3
                                                          HOUSEHOLD PARAMETERS
                                                          FAM POP    120861   85.1
UNITS IN STRUCTURE            HOUSEHOLDS WITH:            INDIVIDS    17033   12.0
1           23612   48.6      TV          43017   46.2    GRP QTRS     4154    2.9
2            5104   10.5      WASHER      18004   19.3    TOT POP    142048
3-4          3170    6.5      DRYER        4825    5.2
5-9          3950    8.1      DISHWSH      2731    2.9   NO OF HH'S        48561
10-49        9630   19.8      AIRCOND     21264   22.8   NO OF FAM'S       35884
50 +         2501    5.1      FREEZER      2706    2.9   AVG HH SIZE         2.9
MOBILE        625    1.3      2 HOMES       542     .6   AVG FAM SIZE        3.4
```

designated by a centroid. To synchronize census data with the aircraft noise information, ALAMO provides demographic data as if it occurred in the centroid of a census tract. Thus, changing demographic configurations around an airport are reflected in the ALAMO output as a given band expands or contracts (thereby varying the number of centroids affected) or as there is movement between specified noise level bands.

This factor was of added importance considering the fact that a relatively large number of ALAMO runs were employed as part of the soundproofing/relocation scenario development. Accordingly, the basic framework of the updating procedure was a need to provide for automatic updating of the ALAMO output without resort to time-consuming inclusion of externally derived site-specific updating parameters. This objective was achieved by a procedure based almost exclusively on the relationship between the rate of change of two demographic variables -- total population and number of households -- and the remaining variables of interest in program costing.* Further, the rate of change for these variables can be determined directly from the ALAMO output since it contains two data points (i.e., 1970 and 1977).

Updating Procedure

The updating was accomplished in two parts. First, selected variables were updated to 1979 values to establish a suitable baseline. Second, the 1979 values were updated to any desired forecast year. The procedure has been computerized in ORI's ALAMO Report Generator Program (DEMCON) whereby the user merely specifies the scenario name and forecast year desired (Reference 11).

The 1970 values for population (P) and households (H) were updated to 1979 baseline values based on their respective annual compound growth rate as follows:

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*The derivation and rationale of the range of variables needed to determine program costing are described in Chapter VI below.

$$X_{1979} = X_{1970}(1+r_X)^9 \qquad (1)$$

$$1 + r_x = \left(\frac{X_y}{X_{19170}}\right)^{1/(y-1970)} \qquad (2)$$

where: X = variable of interest, either population (P) or households (H)

r = compound growth rate

y = year for which updated ALAMO data is available (normally 1977).

Population. Total population in 1979 was estimated by Equations (1) and (2). The distribution of population by race was determined by applying the same percentage distribution for 1970 population in the ALAMO demographic profile report. Similarly, age distribution and median age were held constant at their 1970 values. The male/female distinction in the 1970 census data was dropped for the updates and a composite age distribution presented instead.

Households. Total households in 1979 was similarly calculated by Equations (1) and (2). Average household size was determined by dividing total population by total households. Note that it is possible for a given airport to experience a decline in total population with an increase in renters, homeowners and housing units. This occurs when the compound growth rate for population is less than that for households. This occurs because the size of the "average" family unit is generally declining due to a greater incidence of single-parent families (an out-growth of the increasing divorce rate), fewer children per family and reduced and/or deferred marriages leading to increased single-person families. These factors are reflective of the changing demogra- phic characteristics/of the family unit experienced in the past decade. The reduction in average household size means that a greater housing stock would be needed to accommodate any given population level.

Number of Renters. The total number of renters for 1979 was determined by:

$$R_{1979} = R_{1970}(1+r_H)^9 \tag{3}$$

where: R = number of renters
r_H = compound growth rate for households.

Note that total renters plus total homeowners does not equal total households. This is because more than one household may reside in a single rental or home unit. Equation (3) maintains the number of multiple household units at their 1970 levels.

Percent Renters. This variable was held constant at its 1970 value.

Average/Median Rent. In the absence of airport-specific information on changes in rental values, it was assumed that rents rise in accordance with national trends. While this assumption may have resulted in an over or under estimate of 1979 rental values for a given airport, application of national trends remains appropriate for costing at a national level. Table 4.6 presents consumer price indexes for residential rent and home purchase using 1970 as the index year. Rental values (RV) for 1979 are:

$$RV_{1979} = 1.60\ RV_{1970} \tag{4}$$

where: RV = monthly rental value.

Note that examination of a number of ALAMO profile reports and DEMCON updates showed rental values for 1970 generally in the range of $150 to $300. This range may appear low, especially in reference to the perception of rental values in a large metropolitan area such as Washington, D.C. However, a number of factors would tend to depress rental values around major commercial airports. Such factors are: (1) rent control extant in urban areas; (2) blighted neighborhoods in the vicinity of airports; and (3) the reduced desirability of housing in a high-noise impacted area.

TABLE 4.6

CONSUMER PRICE INDEXES FOR RESIDENTIAL RENT AND HOME PURCHASE, 1965-1979

	RENT*		HOME PURCHASE**	
YEAR	1970 = 1.0	1979 = 1.0	1970 = 1.0	1979 = 1.0
1965	0.88	0.55	0.82	0.43
1966	0.89	0.56	0.83	0.44
1967	0.91	0.57	0.85	0.45
1968	0.93	0.58	0.87	0.46
1969	0.96	0.60	0.93	0.49
1970	1.00	0.63	1.00	0.53
1971	1.05	0.66	1.05	0.56
1972	1.08	0.68	1.10	0.58
1973	1.13	0.71	1.12	0.59
1974	1.19	0.74	1.21	0.64
1975	1.25	0.78	1.36	0.72
1976	1.31	0.82	1.42	0.75
1977	1.39	0.87	1.52	0.80
1978	1.49	0.93	1.66	0.88
1979	1.60	1.00	1.89	1.00

*Source: Economic Report of the President, Transmitted to the Congress January 1980, Table B-49, page 259. Converted from 1968=100.0

**Source: Ibid, Table B-50, page 260. Converted from 1968=100.0

Number of Homeowners. The same procedure used to update number of renters was used as follows:

$$HO_{1979} = HO_{1970} (1+r_H)^9 \qquad (5)$$

where: HO = number of homeowners

r_H = compound growth rate for households.

Percent Homeowners. This variable was held constant at its 1970 value.

Average/Medium Home Value. The national trend for home purchase values (Table 4.6) was used as follows:

$$HV_{1979} = 1.89\ HV_{1970} \qquad (6)$$

where: HV = home value.

As in the case with rental values, close proximity to a major airport tends to depress home values.

Number of Units/Structures. The 1970 ALAMO output presents the number of housing units according to seven structure types, including mobile homes. The total number of units was updated to 1979 values by:

$$U_{1979} = U_{1970} (1+r_H)^9 \qquad (7)$$

where: U = total housing units

r_H = compound growth rate for households.

The total, updated units were then allocated by structure type according to the same percentage distribution extant in 1970. That is, if the housing stock in 1970 consisted of 80 percent single family dwellings, 80 percent of 1979 units would similarly be single family dwellings. Building patterns over the past decade may in fact have caused a shift in the composition of housing structures, as occurred in the vicinity of Washington National Airport with the recent construction of a number of large, multi-unit structures.

Deliniation of such shifts, however, was not possible within the procedural framework for the update presented earlier.

The update for housing structures necessitated a two-step process since total number of structures were not directly delineated in the 1970 ALAMO output. Accordingly, DEMCON first converted units to structures by assuming that a prototype structure consists of the mid-point of the range of units within each structure type as follows:

UNITS PER STRUCTURE

RANGE	AVERAGE
1	1
2	2
3-4	3.5
5-9	7.0
10-49	29.5
50+	75

The number of structures was calculated by dividing the number of units by the average number of units per structure type. The 1970 percentage distribution per structure type was then applied to 1979 values.

Note that mobile homes are excluded from the updating procedure. This was based on the assumption that soundproofing would not be a viable option for mobile homes. Furthermore, the relocation costing procedure developed in Reference 12 (and summarized in Chapter VI) does not apply to mobile homes since the homes would be physically transferred and set in a new development.

The omission of mobile homes would of course tend to underestimate total relocation/soundproofing program costs, but not by a significant amount given to relative scarcity of such homes in the relevant airport noise contour areas.

Update to Post-1979 Values. A different procedure was required to update to post-1979 values. Since program costs were based on constant 1979 dollars, all variables containing a dollar value are held at their 1979 levels (e.g., per capita income, average/median rent and average/median home values). Furthermore, the basic demographic shifts which led to smaller household and family sizes in the past decade were noted earlier. There is, however, a practical limit to the decline in these parameters as, for example, the average household or family size cannot fall below 1.0. The decline in these parameters is expected to level off at current values. Accordingly, the variables also were held constant at their 1979 values.

All of the variables which do change in the post-1979 period do so at the same annual compound growth rate, represented by the growth rate for households, as follows:

$$Z_T = Z_{1979}(1+r_H)^{T-1979} \qquad (8)$$

where: T = the post-1979 year for which an update is desired

Z = variable of interest, namely total population, total households, number of renters, number of homeowners and number of units and structures (totals and by structure type).

Unlike the case for updating to 1979 values, the post-1979 values will not have situations where a declining population may give rise to a larger housing stock. Rather, there is a direct correlation between the rate of change of households and all the other demographic factors represented by the variable "Z".

Under this procedure, a given airport may experience declining population in the period 1970 to 1979 and then increasing population in the post-1979 era. This remains a reasonable inference since, while the size of an average household may decline, the nuclear household will nevertheless continue to produce progeny, leading to a population increase in future years as household size is kept constant. An alternative approach would be use of a coherent survival methodology (Reference 13). However, this approach did not fit within the framework for the updating procedure because: (1) historical airport-specific data was not readily available; and (2) site-specific input of these data (if available) would be required.

REPRESENTATIVE AIRPORT PROGRAM COSTING PROCEDURE

Estimates of the four primary exposure parameters -- total population, number of residences, area and program costs -- were developed for each scenario using selected output and data from the following programs and reports:

- ORI's ALAMO Demographic Report Generator Program or "DEMCOM" (Reference 11).
- FAA's Integrated Noise Model, or "INM" (Reference 15).
- ORI report entitled "Procedures to Estimate Airport Residential Costs" (Reference 12).
- Wyle Laboratories report entitled "A Study of Soundproofing Requirements for Residences Adjacent to Commercial Airports" (Reference 14).

The derivation of the exposure parameters and selected other variables is described below.

Rport Population

Total population for each of the selected Rports was obtained from the ALAMO Demographic Profile Report, as updated by ORI's DEMCOM program (Reference 11). Population is summarized for the soundproofing and relocation phases of the program respectively.

Number of Residences

The number of affected residences was similarly obtained from the direct output of Reference 11. For purposes of this study, the concern was with each residential unit as opposed to the total number of structures which may be exposed to adverse airport noise levels.

Area

Area in square miles for the soundproofing and relocation zones was obtained also from Reference 11.

Program Cost-Soundproofing

The cost of soundproofing was predicated on the stated goal of achieving an interior sound level of L_{dn} 45 dB. Costs per residential dwellings unit to achieve the stated criteria were developed using the following approach (Reference 14). First, the noise reduction of existing units was calculated and combined with the exterior sound levels from airport operations to determine the existing interior levels. The difference between these levels and the stated criteria represents the additional noise reduction to be provided by soundproofing. The modifications necessary to achieve this additional noise reduction were then identified and costed.

The wide range of dwelling types and construction found in the U.S. made it necessary to develop a series of categories. Single-family dwellings were classified into four main types -- one-story, two-story, bi-level and split-level. Multi-family dwellings were classified in terms of the number of units contained, the categories being 2, 3 to 4, 5 to 9, 10 to 49, and greater than 50 units per structure. For each dwelling category, interior configurations were defined describing the number and size of rooms, and the type of construction elements, i.e., wall, roof, floor, etc., present in each room. This data formed the basis for the calculation of noise reduction provided by existing dwellings.

To calculate the noise reduction, the sound transmission characteristics of each construction element were specified in terms of a single number, called the exterior wall rating (EWR) rating. The EWR ratings of typical dwelling elements were defined using a classification scheme covering all constructions common to the U.S. The scheme used the exterior wall and roof construction as the basis for classification, treating other elements as subcategories or potential options that may or may not be present in any dwelling type. The Nation was divided into eleven regions, each one incorporating areas of similar dwelling construction. In this way, it was possible to specify the noise reduction of dwellings on a regional basis, taking local features into account.

To determine the distribution of dwelling types in each region, and to obtain detailed information on local dwelling characteristics that affect noise reduction, field surveys were conducted at one airport in each region. The airports surveyed were selected on the basis that the local dwelling characteristics were representative of the respective region. The information obtained was used to identify the types of modifications most suitable for soundproofing dwellings in each region.

The selection of soundproofing modifications required for construction elements in each dwelling category in each region was made using a cost optimization technique to achieve the interior noise criteria at the least cost. The costs for adding a ventilation system, required to replace the natural ventilation that occurs through leaks in the dwelling structure, were then added to the costs for structural modifications to provide an overall cost for soundproofing. Costs were originally developed in terms of 1981 dollars. However, these estimates were deflated to 1979 dollars for compatibility with the baseline scenario, which is defined as 1979 operations and 1979 demographics.

Total soundproofing costs per Rport were determined by multiplying the cost per residential dwelling unit by the number of units in the respective representative airport.

Regional Soundproofing Costs

As mentioned previously, the cost of soundproofing a residential dwelling unit is strongly influenced by the construction characteristics of the dwelling. The characteristics, in turn, vary considerably in different regions of the country but are fairly consistent within a region. To capture regional variations, the Nation was divided into 11 regions in which construction patterns are fairly homogeneous (see Figure 4.2). A brief description of each region is given below (Reference 14).

Region A: The Pacific Coastline. The climate is relatively mild as far inland as the Sierra Nevada foothills. Additionally, this region contains three major metropolitan sections: San Francisco - Oakland - San Jose complex, Los Angeles - Orange - Riverside - San Bernardino Counties complex, and the San Diego County area. The population concentration is relatively high, bringing with it the influx of skilled trades. Lumber is plentiful as are aggregates for concrete, and most all other standard building materials, explaining the proliferation of stud-and-stucco construction, modified by the higher modified by the higher cost systems such as brick veneers. The higher economic level of a metropolitan and industralized area permits use of more expensive methods and materials for aesthetic purposes. Seismicity for this region is high and is an important consideration.

Region B: Inland Southern California, Southern Nevada, and Southwestern Arizona. Climate is a prime factor; hot, dry summers and relatively mild winters. Closely spaced metropolitan areas do not exist. Lumber is imported, but sand and aggregates for concrete block are plentiful. Therefore, in this region, buildings will have a greater percentage of concrete masonry. As a further incentive, concrete block structures are cool in the long summers. The common stud-and-stucco combination is also popular, as in this region it is again the most economical and durable. Additionally, maintenance is low for stucco in relation to wood, which needs paint more frequently.

Region C: The Gulf Coast and Atlantic Coastline. This region enjoys a relatively mild climate with high humidity, and is subject to violent tropical storms. Clay for brick is relatively abundant, as is local lumber. Therefore, less stud-and-stucco construction is used as it is more susceptible to moisture, and the brick and concrete block construction is more popular. When wood framing is used, it is often protected by brick veneer. Because of the high humidity and generous rainfall, concrete block is often protected by exterior plaster.

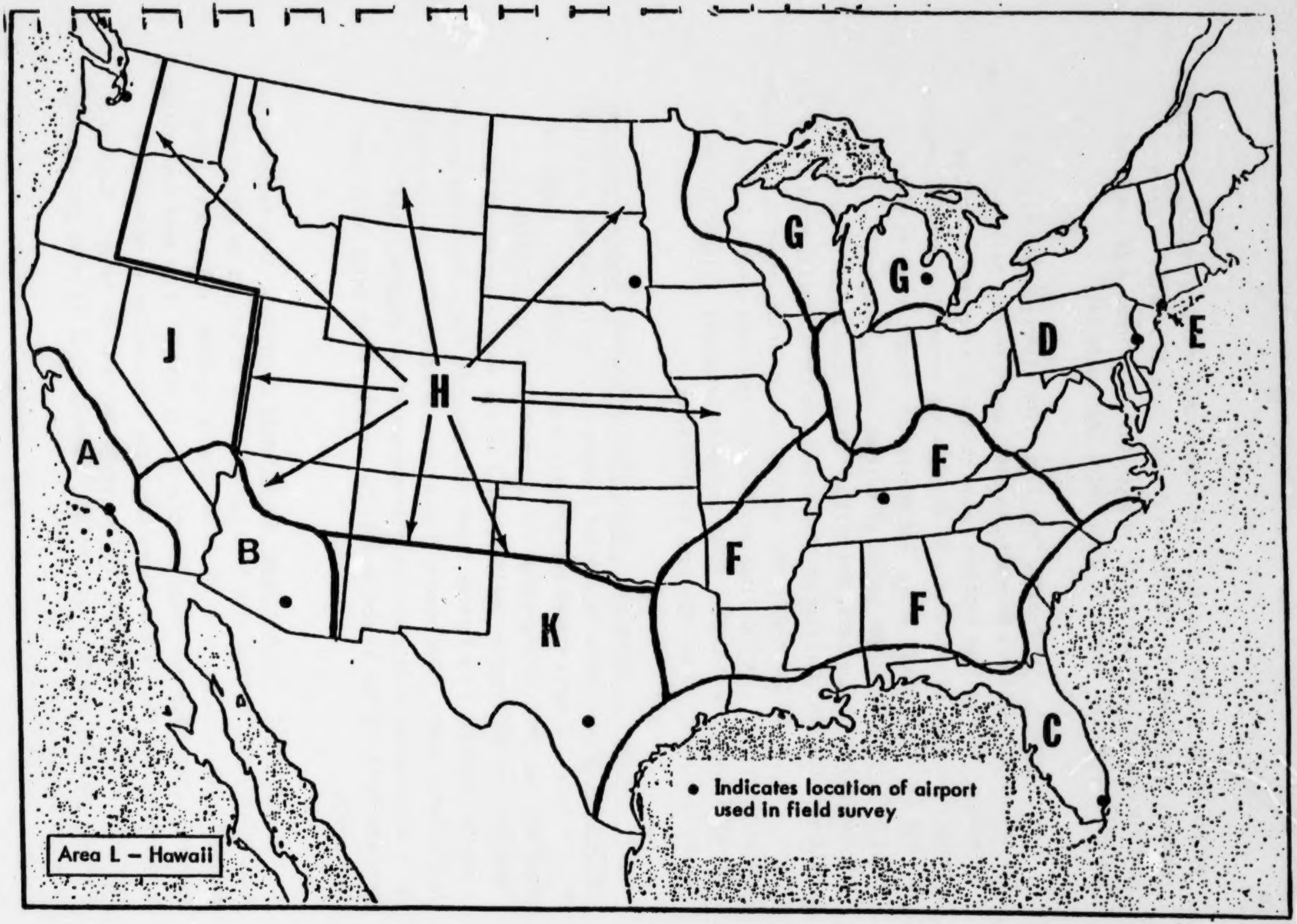

A
B
C
D
E
F
F
F
F
G
G
H
J
K
Area L – Hawaii
• Indicates location of airport used in field survey

FIGURE 4.2. Regions of Differing Construction Practices

Region D: Eastern Seaboard and Inland to Central Illinois. Both climate and concentration of population comprise the prime influence here. The climate is quite cold for half the year and insulation properties are important. Both brick clay and local lumber are available, and the labor availability in all trades is generally good.

Region E: New York City. Single-family dewellings are similar to those found in Region D, but the central urban area consists largely of row houses and high-rise buildings.

Regions F and G: Central South and Great Lakes (Western) States. Although these regions have considerably different climates, the average construction is similar due to economics. Lumber is local and plentiful, as is clay for brick. Away from metropolitan areas, union influences are not so strong, and carpenters are frequently jack-of-all-trades, laying brick and block, installing gypsumboard or plastering.

Regions H, J, and K: Central States. These regions of different climatic conditions are governed more by economics than by climate. Most parts of this region experience below-freezing winters and hot, moderately humid summers. More important, however, is the commonality that, with the exception of very localized spots such as the Seattle-Tacoma area, there is no concentration of urbanization and industrialization. Consequently, the economy of the region is the prime factor, and materials and construction combinations giving best insulation at least cost are predominant. In this region, the carpenter is frequently the general builder. Material influences are again balanced between the easy transportability of lumber and the general local availability of clay for bricks. Thus, the construction norms for different parts of the region are similar for different reasons.

Region L: Hawaii. Generally lightweight construction for walls and roofs, with heavy use of wood products. The climate is mild throughout the year so that insultation is not required.

Average residential soundproofing costs by region and by structure type and L_{dn} are presented in Tables 4.7 to 4.9. Note that the costs vary considerably among the regions. For example, Miami International Airport (which is the Rport representing the 13 airports in Rport category A) is located in Region C. The cost of soundproofing a single unit dwelling in the L_{dn} 65-75 dB contour at Miami is thus $1,975. This amount is considerably higher than the costs for an airport in Region H ($945) and lower for an airport in Region E ($4,125).

Average soundproofing costs for the Rport categories was developed according to the following procedure.

First, the 129 airports contained in the four Rport categories were allocated to their respective regions (see Table 4.10). A weighted average soundproofing cost per residential unit was then determined for each Rport category by multiplying the number of airports within each region by the applicable unit cost. Average costs per structure type and L_{dn} contour are presented in Table 4.11. The average unit cost (by L_{dn} contour and structure type) for each Rport category is then multiplied by the number of residential units for the respective Rport.

Program Cost-Relocation

The cost of relocation of residential properties was based on the purchase of all such properties contained within the applicable relocation zone, defined as either the L_{dn} 75+ dB noise contour or, alternatively, the L_{dn} 80+ dB noise contour. The approach used is as follows (and described in more detail in Chapter VI).

First, the provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 were examined for their potential applicability to the program. While it is not certain that the Act would in fact apply to relocation efforts implemented by an airport proprietor, the Act nonetheless provides a consistent, uniform basis from which costs may be estimated. Cost elements covered by the Act are:

- Advisory service costs incurred by a relocation agency

Region D: Eastern Seaboard and Inland to Central Illinois. Both climate and concentration of population comprise the prime influence here. The climate is quite cold for half the year and insulation properties are important. Both brick clay and local lumber are available, and the labor availability in all trades is generally good.

Region E: New York City. Single-family dewellings are similar to those found in Region D, but the central urban area consists largely of row houses and high-rise buildings.

Regions F and G: Central South and Great Lakes (Western) States. Although these regions have considerably different climates, the average construction is similar due to economics. Lumber is local and plentiful, as is clay for brick. Away from metropolitan areas, union influences are not so strong, and carpenters are frequently jack-of-all-trades, laying brick and block, installing gypsumboard or plastering.

Regions H, J, and K: Central States. These regions of different climatic conditions are governed more by economics than by climate. Most parts of this region experience below-freezing winters and hot, moderately humid summers. More important, however, is the commonality that, with the exception of very localized spots such as the Seattle-Tacoma area, there is no concentration of urbanization and industrialization. Consequently, the economy of the region is the prime factor, and materials and construction combinations giving best insulation at least cost are predominant. In this region, the carpenter is frequently the general builder. Material influences are again balanced between the easy transportability of lumber and the general local availability of clay for bricks. Thus, the construction norms for different parts of the region are similar for different reasons.

Region L: Hawaii. Generally lightweight construction for walls and roofs, with heavy use of wood products. The climate is mild throughout the year so that insultation is not required.

TABLE 4.7

AVERAGE RESIDENTIAL SOUNDPROOFING COSTS: SINGLE-FAMILY DWELLINGS[a]
(1979 Dollars)[b]

L_{dn} Contour / Region	65-70 dB	70-75 dB	75-80 dB
A	2,235	4,980	10,995
B	1,200	2,665	7,045
C	1,975	4,640	9.450
D	2,150	6,355	12,970
E	4,125	8,160	15,465
F	1,545	3,265	8,590
G	2,150	7,300	13,830
H	945	4,295	11,685
J	2,320	6,615	12,800
K	1,805	5,155	10,050
L	3,265	8,935	15,635

[a] Source: Reference 14.

[b] Conversion to 1979 dollars based on U.S. Department of Commerce Composite Construction Cost Indexes of 232.3 and 199.6 for 1979 and April 1981, respectively (Reference 18).

TABLE 4.8

AVERAGE RESIDENTIAL SOUNDPROOFING COSTS: MULTIPLE - FAMILY DWELLINGS[a] (1979 Dollars)[b]

L_{dn} Contour / Region	TWO UNITS			THREE TO FOUR UNITS		
	65-70 dB	70-75 dB	75-80 dB	65-70 dB	70-75 dB	75-80 dB
A	685	2,490	6,015	685	1,890	4,555
B	770	1,630	4,295	770	1,460	3,610
C	685	1,720	2,665	685	1,460	3,610
D	600	1,030	2,575	600	860	2,150
E	600	1,030	2,575	600	860	2,150
F	685	2,920	5,585	600	2,320	4,380
G	685	2,920	5,585	600	2,320	4,380
H	600	1,030	2,575	600	860	1,975
J	685	2,235	4,180	685	1,890	3,865
K	685	2,235	4,895	685	1.890	4,125
L	685	2,150	4,465	685	1,890	4,125

[a] Source: Reference 14.

[b] Conversion to 1979 dollars based on U.S. Department of Commerce Composite Construction Cost Indexes of 232.3 and 199.6 for 1979 and April 1981, respectively, (Reference 18).

TABLE 4.9

AVERAGE RESIDENTIAL SOUNDPROOFING COSTS: MULTI - FAMILY UNITS (>5 UNITS PER STRUCTURE) FOR ALL REGIONS[a] (1979 Dollars)[b]

L_{dn} Zone	Number of Units		
	5-9	10-49	50+
65-70	600	600	600
70-75	770	685	685
75-80	1375	1030	860

[a] Source: Reference 14.

[b] Conversion to 1979 dollars based on U.S. Department of Commerce Composite Construction Cost Indexes of 232.3 and 199.6 for 1979 and April 1981, respectively (Reference 18).

TABLE 4.10

DISTRIBUTION OF AIRPORTS BY SOUNDPROOFING REGION

REGION	RPORT CATEGORY				
	A	B	C	D	Total Airports
A	2	-	4	7	13
B	-	-	3	-	3
C	-	-	3	2	5
D	1	-	6	8	15
E	2	-	5	11	18
F	6	-	10	17	33
G	-	2	-	-	1
H	-	-	3	9	12
J	2	-	6	13	21
K	-	-	3	1	4
L	-	-	1	3	4
Total Airports	13	1	44	71	129

TABLE 4.11

AVERAGE RESIDENTIAL SOUNDPROOFING COSTS BY RPORT CATEGORY

(1979 Dollars)

L_{dn} Contour	STRUCTURE TYPE Single Family	 1-2 Units	 3-4 Units	 5-9 Units	 10-49 Units	 50+ Units
Rport Category A						
65-70 dB	2,210	670	630	600	600	600
70-75 dB	5,030	2,310	1,850	770	685	685
75-80 dB	11,000	4,840	381	1,375	1,030	860
Rport Category B						
65-70 dB	2,150	685	600	600	600	600
70-75 dB	7,300	2,920	2,320	770	685	685
75-80 dB	13,830	5,585	4,380	1,375	1,030	860
Rport Category C						
65-70 dB	2,110	660	640	600	600	600
70-75 dB	5,240	1,950	1,600	770	685	685
75-80 dB	11,190	4,200	3,480	1,375	1,030	860
Rport Category D						
65-70 dB	2,240	650	630	600	600	600
70-75 dB	5,590	1,930	1,570	770	685	685
75-80 dB	11,890	4,160	3,370	1,375	1,030	860

- Moving costs
- Purchase price of rental property
- Purchase price of owner-occupied units
- Replacement costs for tenants and homeowners
- Increased mortgage interest costs
- Closing costs on replacement housing
- Downpayments on replacement housing
- Income foregone for landlords suffering business disruption.

Not all of the cost elements listed above would apply to every person displaced as a result of a relocation effort. Accordingly, four distinct relocation cases were defined to categorize cost elements:

- Case A -- renters who remain renters
- Case B -- renters who become homeowners
- Case C -- rental property to be purchased
- Case D -- owner-occupied units to be purchased.

Costs per element were derived from a combination of national costs (e.g., for mortgage interest rate trends) and cost values specific to the representative airport under study. Examples of the latter are average home values and average monthly rental values within a specified relocation contour.

A summation of the appropriate cost elements lead to derivation of the total cost per relocation case. The final step in the methodology involved multiplying the cost per case by its frequency of occurrence to estimate total Rport relocation costs. Frequencies were similarly determined from a combination of national trends and airport-specific data. The airport-specific data was obtained directly from the ORI DEMCON program output. Such data includes number of renters, number of owner-occupied units and number of rental properties. The mix of renters who upon relocation are likely to remain renters (Case A) or to become homeowners (Case B) was based on national survey data compiled from the Federal Highway Administration's experience under the Relocation Act (Reference 16).

As was the case for soundproofing costs, all relocation costs were estimated in terms of constant 1979 dollars.

NATIONAL NOISE EXPOSURE ESTIMATION PROCEDURE

The concept of the representative airport enables a fairly smooth transition from estimating exposed area and population for the four Rports to estimating the likely magnitude of noise exposure on a national scale. From the Rport development methodology presented in Chapter III, it was noted that the representative airports represent a number of distinct categories of airports. Accordingly, the magnitude of exposure parameters for each Rport should, on average, be fairly representative of the magnitude of all airports within the relevant category. National exposure estimates can thus be estimated by a two-step process as follows. First, parameter values for each Rport are multiplied by the number of airports represented by the Rport. A summation of the resultant category values then provides an estimate for national values.

It bears emphasis here that the results of a national noise exposure estimation procedure are more complex. They are the end result of a considerable amount of preparatory analysis which, as discussed elsewhere in this report, involved manipulation of extremely large data bases, use of a combination of airport-specific and national information and of necessity required the establishment of certain simplifying assumptions. Nevertheless, the approach was intended to improve upon earlier techniques used to determine representative airports and to generate national soundproofing/relocation exposure estimates. The primary ways in which this study differs from previous studies (Reference 17) are that demographic data contributed to the determination of representative airports, real rather than psuedo-airports are used and program exposure estimates were developed from a "bottom-up" approach. When considering any given airport within a Rport category, the extent of its potential noise problem (and, conversely, potential cost of program implementation) may be quite different than that of the representative airport. Unique local features such as terrain, airport layout and nature of air carrier operations are just some of the factors which cause the differences.

NOISE ABATEMENT FLIGHT PROCEDURES

Aircraft are capable of utilizing a variety of safe departure procedures, each of which generates different noise levels and different airport-environs noise exposure patterns. These differences are assessed in the scenarios by examining three takeoff flight procedures.

Takeoff Procedures Description

In general, aircraft initiate takeoff roll with high thrust and small-to-moderate flap settings (takeoff thrust and flaps). Shortly after lift-off, they retract landing gear and by 400 ft. height above the airport (HAA) reach a stabilized all-engine climb speed which permits them to climb at a safe but relatively steep gradient. At specified values of HAA, depending upon the takeoff procedure, the aircraft will retract flaps (cleanup) and reduce or cut back the thrust to a specified setting. At some point in space below 10,000 ft. HAA, the aircraft will climb in a clean configuration, at climb thrust, and at an airspeed not exceeding 250 knots (Keas) equivalent airspeed).

A noise abatement takeoff procedure is an aircraft departure schedule consisting of three flight path segments which can be identified by their principal operational activities:

- Ground roll and initial climb
- Thrust reduction
- Normal climb.

Within each segment may be several sections in which the airplane conducts additional activities such as gear and flap retractions, accelerations to specified speeds, and thrust changes. The locations at which the activities are initiated and their magnitude and duration are the factors that determine the takeoff procedures' effectiveness for noise abatement.

The principal differences in takeoff procedures that influence the noise exposure patterns on the ground are cleanup before initiation of thrust cutback (C/B), or vice versa; extent of cutback thrust (CBT); HAA for cleanup and initiation of CBT; and HAA for reapplication of thrust when CBT is less than maximum climb thrust (MCT). Following are brief descriptions of three takeoff procedures that are examined in this report from the standpoint of noise abatement:

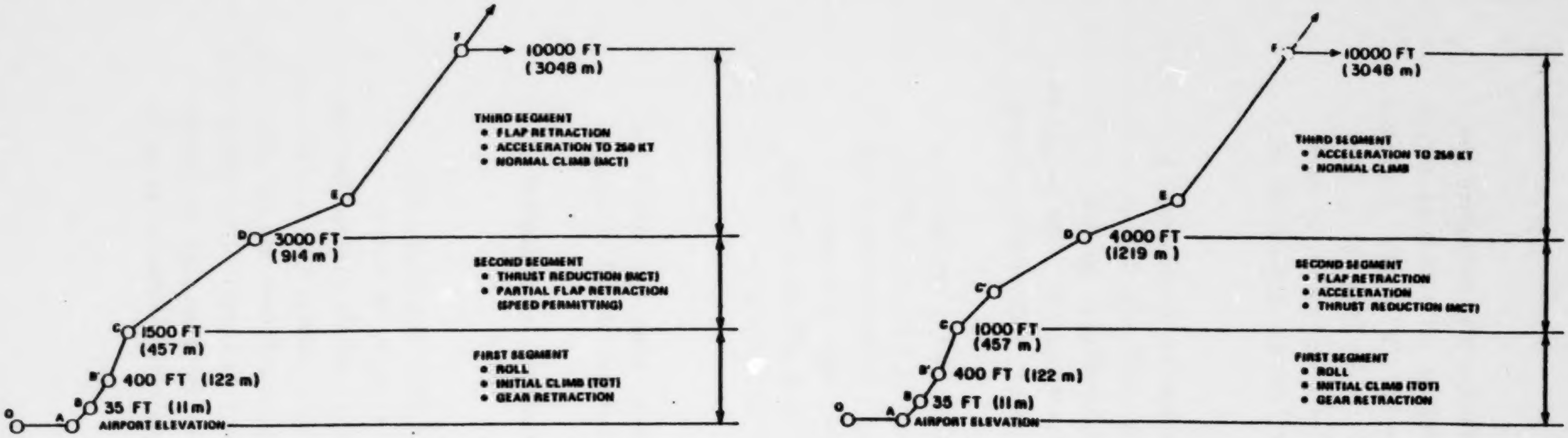
AC 91-39. The Federal Aviation Administration has recommended a departure procedure in Advisory Circular 91-39 which until recently was supported by the Air Transport Association (ATA) as beneficial for the reduction of community noise and pilot work load (Reference 19). The procedure would reduce takeoff thrust (TOT) to maximum climb thrust (MCT) before cleanup.

ALPA/NWA Max. The Airline Pilots Association (ALPA) recommends a procedure which, except for minor details, is similar to the one routinely used by Northwest Airlines (NWA) (Reference 20). Both organizations claim benefits for community noise impact, fuel consumption, wear and tear on engines and safety. The procedure would reduce TOT to a CBT equal to the one-engine-out certification requirement for thrust but only after acceleration and cleanup.

ALPA/NWA Min. This procedure is similar to ALPA/NWA Max except that TOT would be reduced to a CBT equal to MCT after acceleration and cleanup.

Schematics of the three takeoff flight procedures are presented in Figure 4.3.

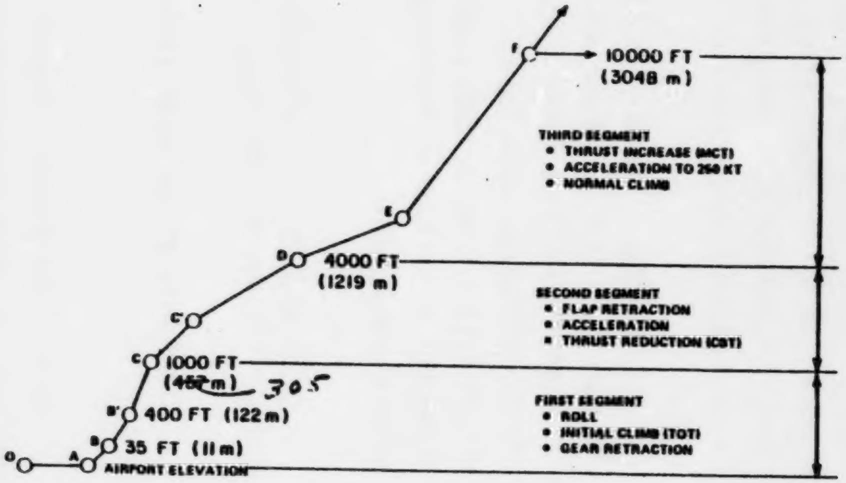
Each of the aircraft takeoff procedures has both advantages and disadvantages for noise control, depending upon the location of noise-sensitive communities. A procedure that reduces thrust before cleanup has the advantage of abating noise sooner than a procedure that reduces thrust after cleanup. However, the noise abatement resulting from the former may be less than the latter and may occur too close to the airport to benefit many people. A procedure that employs a large thrust reduction has the advantage of maximum noise abatement, but would be of no value if noise-sensitive communities were not located where that advantage would be realized.



O
A
B
B'
C
D
E
F
AIRPORT ELEVATION
35 FT (11m)
400 FT (122 m)
1500 FT
(457 m)
3000 FT
(914 m)
10000 FT
(3048 m)
FIRST SEGMENT
• ROLL
• INITIAL CLIMB (TOT)
• GEAR RETRACTION
SECOND SEGMENT
• THRUST REDUCTION (MCT)
• PARTIAL FLAP RETRACTION
(SPEED PERMITTING)
THIRD SEGMENT
• FLAP RETRACTION
• ACCELERATION TO 250 KT
• NORMAL CLIMB (MCT)
O
A
B
B'
C
C'
D
E
F
AIRPORT ELEVATION
35 FT (11m)
400 FT (122 m)
1000 FT
(457 m)
4000 FT
(1219 m)
10000 FT
(3048 m)
FIRST SEGMENT
• ROLL
• INITIAL CLIMB (TOT)
• GEAR RETRACTION
SECOND SEGMENT
• FLAP RETRACTION
• ACCELERATION
• THRUST REDUCTION (MCT)
THIRD SEGMENT
• ACCELERATION TO 250 KT
• NORMAL CLIMB

a. AC 91-39 Flight Procedures

b. ALPA/NWA Min Flight Procedures



O
A
B
B'
C
C'
D
E
F
AIRPORT ELEVATION
35 FT (11m)
400 FT (122m)
1000 FT
(457 m)
305
4000 FT
(1219 m)
10000 FT
(3048 m)
FIRST SEGMENT
• ROLL
• INITIAL CLIMB (TOT)
• GEAR RETRACTION
SECOND SEGMENT
• FLAP RETRACTION
• ACCELERATION
• THRUST REDUCTION (CST)
THIRD SEGMENT
• THRUST INCREASE (MCT)
• ACCELERATION TO 250 KT
• NORMAL CLIMB

c. ALPA/NWA Max Flight Procedures

FIGURE 4.3. TAKEOFF FLIGHT PROCEDURE PROFILES

A procedure that reduces power below climb thrust in order to minimize the noise exposure for one community must ultimately reapply power to climb thrust, which may increase the exposure for another community. When comparing two procedures, one with larger thrust cutback than the other, there will be a crossover point at which both procedures will produce the same noise level on the flight track. Inside the crossover point (toward the airport), the larger cutback procedure will produce less noise, but outside the crossover point, the reverse is true (Reference 21).

Procedures to Assess Noise Abatement Impacts

The noise abatement implications of the three flight procedures were quantified in terms of the four general exposure parameters by means of the ALAMO program output. Recall from Chapter III that a complete INM run is required as input to ALAMO. The INM, in turn, requires as input detailed aircraft flight path and performance schedule data. Separate schedules had to be developed for the AC 91-39, ALPA/NWA MAX and ALPA/NWA Min flight procedures.*

Modified analytical algorithms for constructing aircraft flight path and performance schedules for the specified operational procedures were developed from References 22 and 23. These algorithms were derived from fundamental aircraft and performance relationships or from operational characteristics applicable to specific aircraft types. Based on these algorithms, a computer model was developed with which the requisite INM input data were generated.

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*Schedules for the AC 91-39 procedures had to be independently developed to ensure consistency with the other two procedures.

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V. SCENARIO DESCRIPTION AND PROGRAM IMPACT

The stage has been set in the prior chapters for the presentation of scenarios which capture the impacts of selected airport noise control measures. Impact quantification is achieved by examining the four exposure parameters in both absolute and relative terms. Scenarios in turn are developed by varying four major factors which strongly influence the extent of airport-community noise exposure, namely:

- Air carrier fleet year -- incorporates the mix of aircraft types and series in either the baseline 1979 or selected forecast year
- Demographic year -- reflects growth, if any, in population and demographic variables
- Flight procedures -- reflects one of three takeoff flight procedures
- Airport procedures -- reflects use of priority runways and flight tracks.

A fifth factor, extent of soundproofing assistance zone, does not directly impact noise exposure. Rather, it relates to program cost by examining the benefits of offering soundproofing in lieu of relocation assistance to residences within the L_{dn} 75 to 80 dB contour zone.

SCENARIO DESCRIPTION

When the term "scenario" is used, it applies to a discrete set of assumptions for each of the four factors. For example, scenario 2.3 refers to: (1) year 2000 fleet mix; (2) demographic data held constant at values projected to year 1990; (3) use of takeoff flight procedure AC 91-39; and (4) even distribution of operation on appropriate runways and straight in and out flight tracks.

The term "scenario group" refers to a combination of scenarios according to noise abatement alternative. The five scenario groups are described below and summarized in Table 5.1 in reference to national population, area and residences exposure estimates. Selected exposure parameters for the four Rports are provided in Appendix A.

BASELINE AIR CARRIER FLEET

This scenario group reflects a situation whereby the fleet mix and level of air carrier operations change over time from 1979 base values through forecast year 2000. Land use patterns are assumed to continue to evolve much as they had in the pre-1979 era. This is represented by updating the demographic variables to the corresponding fleet mix year.

Note that as the fleet mix changes over time, a greater number of existing, relatively noisy aircraft are replaced by newer, quieter aircraft types and series (see Chapter IV). The result is a dramatic reduction over time in the number of people exposed to adverse airport noise levels, even in the face of population growth in affected airport communities and increases in aircraft departures.

National exposure parameters for years 1979, 1990 and 2000 are presented in Table 5.2. Total population exposed to noise levels in excess of L_{dn} 65 dB drops from 7.6 million in 1979 to 3.6 million in 2000, a decrease of 53 percent. The decrease in population exposure is even greater in the greater than L_{dn} 75 dB noise contour (65 percent) than in the L_{dn} 65 to 75 dB contour (51 percent). This is because areas of highest noise impact tend to be closer to the airport boundary and conversely areas with lesser impact

TABLE 5.1

NATIONAL NOISE EXPOSURE SCENARIO SUMMARY

Scenario Number	Fleet Year	Demographic Year	Flight Procedures	Flight Track	EXPOSURE PARAMETERS Population[b/]	Area	Residences[b/]
Baseline Aircarrier Fleet:							
1.1	1979	1979	AC 91-39	Straight	7,553	2,707	2,940
1.2	1990	1990	AC 91-39	Straight	5,250	1,756	2,049
1.3	2000	2000	AC 91-39	Straight	3,628	1,073	1,369
Land Use Control Implications:							
2.1	1990	1979	AC 91-39	Straight	4,376	1,756	1,713
2.2	2000	1979	AC 91-39	Straight	2,287	1,073	873
2.3	2000	1990	AC 91-39	Straight	2,885	1,073	1,014
Alternative Flight Procedures:							
3.1	1979	1979	ALPA/NWA MIN	Straight	6,583	1,660	2,555
3.2	2000	2000	ALPA/NWA MIN	Straight	4,290	1,294	1,631
3.3	1979	1979	ALPA/NWA MAX	Straight	5,117	2,123	1,922
3.4	2000	2000	ALPA/NWA MAX	Straight	4,898	1,370	1,845
Alternative Flight Tracks:							
4.1	1979	1979	AC 91-39	Curved	3,014	2,548	1,186
4.2	1990	1979	AC 91-39	Curved	1,756	1,654	687
4.3	2000	1979	AC 91-39	Curved	834	1,001	320
Noise Abatement Combinations[a/]:							
5.1	2000	1990	ALPA/NWA MIN	1-3	3,472	1,294	1,328
5.2	2000	1979	ALPA/NWA MIN	1-3	2,830	1,294	1,089
5.3	2000	1990	ALPA/NWA MAX	1-3	3,980	1,370	1,506
5.4	2000	1979	ALPA/NWA MAX	1-3	3,231	1,370	1,243

[a/] Reflects implications of land use control for alternative flight procedures and noise source control.
[b/] Population and area in thousands.

TABLE 5.2

NATIONAL NOISE EXPOSURE ASSOCIATED WITH CHANGES IN AIRCRAFT FLEET MIX AND OPERATIONS

EXPOSURE PARAMETER	NOISE LEVEL (LDN) 65 to 75	75+	TOTAL
1979 Fleet			
Population (1,000's)	7,160	394	7,553
Area (Sq. Miles)	2,286	420	2,707
Residences (1,000's)	2,805	135	2,940
1990 Fleet			
Population (1,000's)	4,962	288	5,250
Area (Sq. Miles)	1,453	303	1,756
Residences (1,000's)	1,954	95	2,049
2000 Fleet			
Population (1,000's)	3,489	139	3,628
Area (Sq. Miles)	894	178	1,073
Residences (1,000's)	1,328	41	1,369

tend to be further removed. High impact areas are also concentrated at runway ends. As aircraft source levels are reduced, the noise contours tend to shrink in towards the airport boundary. Once inside the boundary, there is no community impact due to the lack of residential properties.

The relationship between area and population in the context of shrinking noise contours is presented in Tables 5.3 and 5.4 for the Miami and San Antonio Rports. In 1979, both Rports show a population impact for all contour bands except L_{dn} 85 + dB. Both area and population impact are less in 1990, but more significantly the shrinking contours result in the partial subsuming of the L_{dn} 80 + dB contours either within the airport boundaries or within areas with no residential development. The inward migration of all contours also causes residences in the outer contour bands no longer to be impacted by adverse airport noise levels. For example, as Miami's L_{dn} 65 to 70 dB contour shrinks from 46.3 to 13.4 square miles between 1979 and 2000, respectively, the noise problem is in essence eliminated for residences in a 32.9 square mile area. A similar situation is extant in San Antonio. Note, however, that this Rport shows a reduction in impacted area between 1990 and 2000 but that population actually increases during the 10 year period. This is caused by a population growth rate high enough to more than offset the substantial reduction in noise impacted area.

LAND USE CONTROL IMPLICATIONS

A major problem faced by many air carrier airports is the encroachment of non-compatible residential construction into areas adversely impacted by airport noise. Airport proprietors find that the benefits which might otherwise accrue from noise abatement actions are more than offset by this encroachment (see, for example, Table 5.4). Thus, while the area exposed to say L_{dn} 75+ dB contracts over time, more people and residences are affected due to demographic growth.

Agressive noise compatiblity planning and implementation would help assure that noise control benefits are actually achieved, as measured by an absolute decrease in population exposed. The analytical tools available for this study did not permit site-specific examination of local land use

TABLE 5-3

RELATIONSHIP OF IMPACTS AREA TO POPULATION[a]
(Miami Rport)

Contour Band (L_{dn} d B)	1979		1990		2000		2030	
	Area	Population	Area	Population	Area	Population	Area	Population
55-60	229.6	179.0	139.1	173.3	87.4	119.9	109.0	125.5
60-65	100.6	136.7	70.1	148.3	37.0	127.1	47.5	124.5
65-70	46.3	142.1	28.3	108.2	13.4	65.6	17.0	77.7
70-75	14.4	73.8	9.2	57.9	6.5	30.4	7.9	40.7
75-80	6.5	11.8	4.8	5.8	2.5	0.8	3.1	3.8
80-85	2.8	1.3	1.9	1.4	1.0	1.7	1.3	1.7
85+	1.8	-	1.4	-	0.8	-	1.0	-
65-75	60.7	216.0	37.5	166.1	19.1	95.9	24.9	118.5
75+	11.1	13.1	8.1	7.2	4.4	2.5	5.3	5.4

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[a] Area in square miles; population in thousands.

TABLE 5-4

RELATIONSHIP OF IMPACTED AREA TO POPULATION[a]
(San Antonio Rport)

Contour Band (L_{dn} dB)	1979		1990		2000	
	Area	Population	Area	Population	Area	Population
55-60	106.6	153.8	58.5	123.4	34.3	79.6
60-65	51.1	88.8	24.6	70.6	14.5	78.8
65-70	17.3	48.0	9.0	21.5	6.5	15.0
70-75	6.6	16.3	4.2	18.8	3.2	26.6
75-80	2.7	1.6	1.7	1.6	1.3	-
80-85	1.0	-	0.6	-	0.4	-
85+	0.7	-	0.4	-	0.3	-
65-70	23.9	64.2	13.2	40.4	9.7	41.6
75+	4.4	1.6	2.8	1.6	2.0	-

---

[a] Area in square miles; population in thousands.

patterns. As a proxy for land use control, normal demographic growth for each Rport was held constant at selected years. There is a certain amount of lead time associated with implementaton of any major new program. A comprehensive soundproofing/relocation program certainly would not be an exception to this general proposition. A lead time of 10 years is thus assumed. That is, for fleet mix year 2000, demographic values are held constant at their 1990 levels. Holding these values constant at 1979 levels also is presented to quantify the "opportunity" loss caused by program lead time.

Two points are useful in clarifying land use implications. First, the area impacted for any given fleet mix remains the same with or without land use controls. What land use controls do is to vary the affected population and residences for a constant area. Second, all program costs are in terms of 1979 dollars. Thus variables which are monetized (such as average home value) do not change over time. Only non-monetized variables change, such as number of homeowners. The table immediately below summarizes the benefits of land use control which restricts growth in areas of high airport noise.

	Year 2000 Population (in thousands) by L_{dn} Contour		
Land Use Control Implications	65 to 75	75+	Total
Unrestricted Population Growth	3,489	139	3,628
No Growth After 1990	2,766	119	2,885
No Growth After 1979	2,185	101	2,287

A measure of the opportunity loss is that population growth between years 1979 and 2000 would expose an additional 1.4 million people to adverse noise levels. Another way to look at land use control is to consider that over the 21 year period, there would be a major turn-over in population. Many people currently living in a high noise area would move out, to be replaced by new residents migrating into the area. If population attrition was not replaced, the opportunity loss would be even greater.

ALTERNATIVE FLIGHT PROCEDURES

The general characteristics of the three takeoff flight procedures examined in this study were described in Chapter IV. Unlike the abatement measures discussed above, use of alternative flight procedures does not offer the opportunity for generally uniform improvements in airport-environs noise levels. All three takeoff flight procedures are comprised of three flight path segments which are identified by their principal operational activities.* However, the procedures differ with respect to the location at which these activities are initiated and the sequence of their occurrence. Thus, a procedure which specifies thrust reduction early in the takeoff operation would tend to reduce noise levels close-in to the airport boundary. However, thrust must later be reapplied thereby increasing noise exposure to areas further removed. The net result is that the procedures tend to shift the locus and intensity of impacts between areas.

A "cross-over" point is represented in Table 5.5 which compares the impact of the three flight procedures for the La Guardia Rport for fleet year 1979. The AC 91-39 procedure has the advantage of reducing noise exposure to areas most severely affected by airport noise, namely the greater than L_{dn} 75 dB contours. However, these areas are relatively small and generally have lower population densities. This is to be expected since the areas contain the airport proper, safety considerations limit the height and location of residential structures and the high noise levels tend to make the area unattractive for residential development.

The cross-over point is reached near the end of the L_{dn} 70 to 75 dB contour band. Here, area impacted is greater both relative to the other flight procedures and to the area closer in to the airport. As a general rule, the greater the area impacted, the greater the population impacted.

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*The aircraft performs various operational activities such as landing gear retraction, flap retraction, acceleration and thrust adjustments.

TABLE 5-5

AREA IMPACT OF ALTERNATIVE FLIGHT PROCEDURES LA GUARDIA RPORT (Square Miles)

Noise Contour (L_{dn} dB)	FLIGHT PROCEDURE		
	AC 91-39	ALPA/NWA MIN	ALPA/NWA MAX
60-65	106.1	94.1	95.2
65-70	46.2	37.4	19.4
70-75*	15.2	13.0	10.3
75-80	5.9	7.2	6.9
80-85	2.4	3.4	3.3
85+	1.4	1.5	1.5

*Denotes "cross-over" point where AC 91-39 flight procedures results in relatively greater noise exposure.

The effects of the ALPA/NWA Min flight procedures are basically the converse of those for the AC 91-39 procedure. Impacts increase closer to the airport boundary and decrease further away. The ALPA/NWA Max procedures generally produces the same results, except that noise abatement is significantly greater in the L_{dn} 65 to 75 dB contour area.

Total population exposed to adverse noise levels for fleet year 1979 (from Table 5.1) for the three flight procedures is estimated as follows:

- AC 91-39 -- 7.6 million
- ALPA/NWA Min -- 6.6 million
- ALPA/NWA Max -- 5.1 million

Population impacts by L_{dn} dB contour for the four Rports and on a national basis are summarized in Table 5.6. Note that the ALPA/NWA Max procedure more than doubles the population exposed to L_{dn} 75 + dB as compared to the AC 91-39 procedure. The question thus arises who should be offered relief? The choice becomes one of the greatest good for the greatest number versus concentrating first on those most severely impacted.

An interesting phenomena occurs in the post-1979 period. For fleet year 2000, total population exposed is:

- AC 92-39 -- 3.6 million
- ALPA/NWA Min -- 4.3 million
- ALPA/NWA Max -- 4.9 million

Here not only does the AC 91-39 procedure result in the lowest population impact, but program costs are lowest as well. The AC 91-39 procedure results in lower impact for both the L_{dn} 65 to 70 dB and the L_{dn} 75 + dB contour areas (see Table 5.6). The primary reason is that the air carrier fleet mix has changed to generally replace aircraft powered by low by-pass ratio engines

TABLE 5-6
POPULATION IMPACT OF ALTERNATIVE FLIGHT PROCEDURES
(thousands)

	1979 Fleet Year			2000 Fleet Year		
RPORT	65-70	70-75	75+	65-70	70-75	75+
La Guardia, NY						
AC 91-39	983.5	353.9	83.6	34.2	136.9	15.2
ALPA/NWA MIN	824.1	295.2	121.9	172.8	63.0	19.1
ALPA/NWA MAX	526.8	209.7	112.5	274.9	92.8	19.6
Miami, FL						
AC 91-39	142.1	73.9	13.1	30.4	65.6	2.5
ALPA/NWA MIN	120.5	61.7	24.3	64.4	40.7	5.5
ALPA/NWA MAX	79.0	46.6	22.2	47.1	62.1	5.5
San Antonio, TX						
AC 91-39	48.0	16.3	1.6	15.0	26.6	-
ALPA/NWA MIN	38.4	10.7	3.9	25.3	26.6	-
ALPA/NWA MAX	24.8	17.2	3.7	34.5	26.6	-
Sioux Falls, SD						
AC 91-39	2.0	0.7	1.0	3.4	-	1.3
ALPA/NWA MIN	1.8	2.0	0.9	3.2	-	1.3
ALPA/NWA MAX	1.8	2.0	0.9	3.4	-	1.3
National						
AC 91-39	5085.0	2081.0	394.0	1,331.0	2,160.0	139.0
ALPA/NWA MIN	4208.0	1710.0	670.0	2,350.0	1,762.0	182.0
ALPA/NWA MAX	2773.0	1714.3	891.0	2,647.0	2,070.0	183.0

with aircraft powered by high by-pass ratio engines. Reduced thrust levels achievable with the high by-pass ratio engines does not result in as much noise reduction. Thus the AC 91-39 procedure (which achieves more altitude) is much more attractive from a noise abatement viewpoint.

An airport proprietor might well consider employing the ALPA/NWA Min or Max procedures in the near-term, and then shift to the AC 91-39 procedure in the mid-term as changes in fleet composition warrant. The noise prediction methods discussed elsewhere in this report and in the FAA's Part 150 rule offer the opportunity to select the most appropraite flight procedures consistent with an airport's overall noise abatement policy.

EXPANDED SOUNDPROOFING ZONE

This scenario group explores the advantages of expanding the soundproofing assistance area from L_{dn} 65 to 75 dB to L_{dn} 65 to 80 dB. As mentioned previously, this option would not affect the number of people affected by adverse airport-environs noise levels, but instead provides a procedure which can be adapted to the type of housing and housing patterns at an airport. It also provides a mechanism to better accommodate the desires of residents for whom soundproofing or relocation is proposed.

Soundproofing Zone Selection

The primary soundproofing zone was selected based on a number of factors. First was the feasibility of soundproofing residential units to achieve the desired goal of an interior noise not to exceed L_{dn} 45 dB. There was the recognition that while soundproofing might not be wholly satisfactory to impacted people because their enjoyment of the outdoors would still be limited, they could at least escape to the privacy of their homes and enjoy a good night's sleep, family conversation and relaxation around the television or stereo without the nerve-racking disruption of over-flying aircraft. But there nevertheless are limits to the level of outdoor noise that people should be forced to endue on a long-term, sustaining basis. If the outdoor sound level is too excessive, the escape to the indoors might be tantamount to confinement. The pleasure of outdoor sports, picnics or just relaxing in the sun would largely be removed. Another factor concerned the cost of soundproofing: the greater the attentuation required to achieve an interior level of L_{dn} 45 dB, the greater the associated costs. The general soundproofing modifications are:

- L_{dn} 65 to 70 dB -- sealing leaks and improving weatherstripping
- L_{dn} 70-75 -- as above, plus installation of storm windows, storm doors and roof insulation, as necessary
- L_{dn} 75-80 -- as above, plus modification of walls to include addition of insulation, as necessary.

As would be expected, the greater the sound attenuation needed to achieve an interior level of L_{dn} 45 dB, the more extensive the modifications must be and costs are increased accordingly.

Consideration of the expanded soundproofing zone was similarly based on technological, cost and compatibility with living conditions. Soundproofing apartments where people normally do not spend an appreciable amount of time on the grounds outside the building should impose a minimum impact on the life style of the residents. This is particularly relevent when soundproofing provides a program alternative to relocation. Recent studies on soundproofing practices have demonstrated that adequate attenuation can be provided for residences in areas exposed to an L_{dn} 75 to 80 dB noise level. The associated costs, although higher compared to the primary soundproofing zone, are not excessive. Taking average costs for Rport category C as an example (see Table 4.11), soundproofing a single unit structure is estimated to cost $5,240 in the L_{dn} 70 to 75 dB contour and $11,190 in the L_{dn} 75 to 80 dB contour, an increase of 113 percent. However, as the number of units per structure increases, the structural modifications are less and the cost multiple is significantly reduced. For example, the cost differential for structures of greater than 50 units is much more attractive in both an absolute and relative sense (i.e., $685 versus $860, a 26 percent increase). An analysis of 10 airports, which included the four study Rports, compared total soundproofing/relocation costs with the relocation threshold at L_{dn} 75 dB versus L_{dn} 80 dB. Total program costs for the 10 airports was 65 percent for the expanded soundproofing zone.

The policy implications of an expanded soundproofing zone involve important trade-offs. Enjoyment of the outdoors would of course be more severely impaired given the higher outdoor noise levels. But soundproofing does offer the possibility of minimizing the social, economic and political disruption which might otherwise be associated with a broad relocation effort. This point is the crucial factor: soundproofing becomes an option for relocation. And this option need not apply across the board for all residences within an L_{dn} 75 to 80 dB contour.*

The Chapter II issue analysis noted that the contour lines are not precise, but are subject to a margin of error. Also, a relocation area in all likelihood would not be inflexibly defined. It would tend to follow natural boundaries such as roads or streams and would tend to avoid bifurcating small neighborhood enclaves. Furthermore, local residents, although desiring to be afforded relief from excess noise levels, might vehemently oppose a relocation effort. Opposition is likely to be more pronounced if relocation resulted in the split-up of ethnic and other neighborhoods where a strong sense of community ties exists.

Program Exposure Implication

An expansion of the soundproofing zone means that residences which would otherwise be candidates for relocation would become candidates for soundproofing. Since per unit costs are significantly less for soundproofing, the shift would reduce total implementation costs. This relationship is presented in Table 5.7 for the Miami Rport and for fleet year 1979. Combined costs per residential unit are estimated at \$3,691, comprised of an average unit cost of \$2,054 for soundproofing and \$34,480 for relocation. The expanded zone lowers combined unit costs to \$2,530, a 31 percent reduction.

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*The study impact estimation procedure did not allow for a split of soundproofing and relocation within a given contour area. However, comparison of impacts associated with a primary versus an expanding soundproofing zone does provide insights into the implication of a mixed relocation and soundproofing effort.

TABLE 5-7

COMPARISON OF PRIMARY AND EXPANDED SOUNDPROOFING ZONES
Miami Rport

Expesure Parameter	Soundproofing	.Relocation	Total
Primary Zone[a)]			
Population (thousands)	216.0	13.1	229.1
Area (square miles)	60.7	11.1	71.5
Residences (thousands)	94.0	5.0	99.0
Program Costs ($ millions)	193.1	172.4	365.4
Cost per Residence	2,054	34,480	3,691
Expanded Zone[b)]			
Population (thousands)	227.8	1.3	229.1
Area (square miles)	67.1	4.6	71.8
Residences (thousands)	98.8	0.5	99.3
Program Costs ($ millions)	233.5	17.7	251.2
Cost per Residence	2,363	35,400	2,530

[a)] Defined as L_{dn} 65 to 75 dB for soundproofing eligibility; L_{dn} 75 + for relocation eligibility.

[b)] Defined as L_{dn} 65 to 80 dB for soundproofing eligibility; L_{dn} 80 + for relocation eligibility.

[c)] Variation in total residences due to application of different grow rates for demographic updates.

Soundproofing unit costs are higher under this option, since costs are uniformly greater the more attentuation is required. The example for the Miami Rport also shows a slight increase in relocation costs (3 percent). However, such an increase would not occur in all situations. Rather, unit relocation costs are strongly dependent on housing values. At many commercial air carrier airports experiencing adverse noise levels, the quality of the housing stock is less the closer the residence is to the airport boundary (where noise levels are generally the highest). The result is the expanding soundproofing zone may actually decrease relocation unit costs. On a total program cost basis, the option would offer a reduction from $365 million to $251 million.

As the fleet mix changes over time, however, the program cost savings of an expanded soundproofing zone are not as pronounced. This is primarily attributable to the use of quieted aircraft which achieve the greatest reduction in noise exposure for areas closest to the airport. By the year 2000, there are proportionally fewer residences in the L_{dn} 75 to 80 dB contour area, with less attendant cost savings of an expanded soundproofing zone.

AIRPORT PROCEDURES

Calculation of the percent reduction in the number of people impacted by aircraft noise at a given level as a result of going from straight in and out flight tracks with even runway distribution of take-off operations to the use of preferrential runways and curved flight tracks involves several approximations. Not having complete information on localized situations in this study, some opportunities for improvement are missed and some assumed opportunities would not work out as expected. It is also recognized that some airports currently are using preferential runways to lower the noise impact on people.

Other airports are using runways which point toward aircraft destinations which happen to increase the number of people impacted by a given aircraft noise level. Thus, both the base calculation of the aircraft noise exposure used in this study as representing current and future operations and the percent reduction in noise predicted to result from the use of preferential runways and curved flight tracks are approximations. Only by making studies at individual airports can the noise exposure reduction be accurately determined.

A comparison of the potential benefits of using alternative airport procedures is presented below:

	Population (1,000's)	
Fleet Year	Straight	Curved
1979	7,553	3,014
1990	4,376	1,756
2000	2,287	834

The exposure estimates, summarized from Table 5.1, are based on restricting demographic change to 1979 values. Reducations in population exposed to noise levels in excess of L_{dn} 65 dB range within a narrow band of 36 to 40 percent for the three years considered. It is interesting to note, however, that impact area is reduced by less than 7 percent. This result is to be expected when it is noted that alternative airport procedures have minimal impact on noise reduction; rather, the procedures redirect the impact to areas with relatively less population density.

The majority of this study focused on the four Rports. For alternative flight procedures, six additional airports were considered to better capture the widely varying demographic patterns around the Nation's airports. Population exposure related to these ten airports is presented in Table 5.8. For these airports as a group, alternative airport procedures reduce population exposure by 50 percent as compared to the 36 to 40 percent reduction noted above. However, the reduction varies considerably among the airports. For example, La Guardia is virtually surrounded by fairly dense housing patterns thus making it difficult to re-direct aircraft operations to minimize population exposure. The reverse is the case for airports such as Los Angeles, where a significant number of daily operations can (and are) directed over the Pacific Ocean thereby virtually avoiding developed areas. Where water barriers exist, the benefits of alternative airport procedures can be expected to continue into the future. Such may not be case for land-locked

TABLE 5.8

POPULATION COMPARISON OF STRAIGHT VERSUS CURVED FLIGHT TRACKS AND PRIORITY RUNWAYS (1979)

AIRPORT	STRAIGHT	CURVED	PERCENT REDUCTION
Dayton (DAY)	9,745	2,270	77
Sioux Falls (FSD)	3,630	982	73
Indiannapolis (IND)	17,915	7,798	56
Los Angeles (LAX)	399,276	102,957	74
Memphis (MEM)	106,045	40,529	62
Chicago (ORD)	657,495	174,882	73
New York Kennedy (JFK)	380,306	224,938	41
San Antonio (SAT)	65,828	23,833	64
Miami (MIA)	229,177	76,688	67
New York La Guardia (LGA)	1,420,954	1,001,241	30
TOTAL	3,290,371	1,656,108	50

airports surrounded by land suitable for development but not as yet appreciably occupied. Absent land use compatibility controls, options with respect to alternative airport procedures may well be limited over time.

SUMMARY

It is evident from the preceding discussion that an airport proprietor has available an number of options and perspectives from which to address the airport-community noise exposure problem. But for all Rports addressed in the study (which are in turn representative of 129 actual airports), the noise control options would not eliminate adverse noise impact by the year 2000. They merely provide mechanisms by which the residual noise problem might be minimized.

Five general perspectives may be used in selected options. These are:

- Minimize total soundproofing/relocation program costs
- Minimize the highest adverse noise exposure
- Minimize total adverse noise exposure
- Minimize residential relocation.
- Prevent additional incompatibilities.

Implementation of effective noise compatibility land use controls would promote all policy options by preventing encroachment into noise sensitive areas. Consideration of an expanded soundproofing zone would reduce total program costs and minimize residential relocation by limiting eligibility for this type of assistance. Consideration of alternative flight procedures offers a mixed bag of benefits. For fleet year 1979, the ALPA/NWA procedures reduce the noise exposure for residents furthest from the airport but increase exposure for areas closer in. The net effect is that total adverse noise exposure is reduced but total program costs are greater due to the greater incidence of relocation eligibility (i.e., exposure to L_{dn} 75 +

dB increases). The converse holds for the AC 91-39 procedures. For fleet year 2000, the AC 91-39 procedures would have a beneficial impact on all policy options.

The magnitude of the policy option impacts varies among Rports and, by definition, AVport categories. Table 5.9 summarizes the population exposure and program costs for fleet year 2000 and the AC 91-39 flight procedures. The baseline case refers to year 2000 demographics and land use control is assumed to limit population change to 1990 levels. The 1990 demographic year applies to the expanded soundproofing zone.

The projected statistics show that LaGuardia actually increases population levels between years 1990 and 2000. This results from the projection methodology which applied the pre-1979 growth rate to future years. For LaGuardia, the rate was negative. This does not, however, mean that land use control offers a disbenefit. As noted previously, the methodology could not capture the impact of population and residential construction turn-over. The cost benefit of an expanded soundproofing zone is substantial due to the relatively large population residing the L_{dn} 75 to 80 dB contour.

The Miami Rport was projected to experience moderate population growth, leading to a moderate benefit of land use control. The expanded soundproofing zone option would change the mix of relocation versus soundproofing assistance for some 700 people. Total program costs would be reduced accordingly.

For San Antonio, the projected demographic growth rates are quite high, leading to a significant reduction in population exposure resulting from land use controls. Note that the lack of people in relocation zone. This results from a combination of the use of quieted aircraft and the general lack of residences close to the airport boundary.

The converse is true for the Sioux Falls Rport. Here, there is a pocket of people extremely close to the airport boundary who even in year 2000 would be exposed to noise levels in excess of L_{dn} 75 dB.

TABLE 5.9

COMPARISON OF ABATEMENT ALTERNATIVES[a]
(Fleet Year 2000)

	Population Exposed (Thousands)			Program Cost
RPORTS	Soundproofing	Relocation	Total	($ Millions)
LaGuardia, NY				
Baseline	171.1	15.2	186.3	191.1
Land Use Control	173.9	15.2	189.1	192.0
Expanded Soundproofing Zone	186.4	2.7	189.1	125.8
Miami, FL				
Baseline	95.9	2.5	98.4	122.6
Land Use Control	81.8	2.1	83.9	100.6
Expanded Soundproofing Zone	82.4	1.4	83.9	97.1
San Antonio, TX				
Baseline	41.7	-	41.7	41.5
Land Use Control	29.9	-	30.0	27.7
Expanded Soundproofing Zone	30.0	-	30.0	27.6
Sioux Falls, SD				
Baseline	3.4	1.3	4.6	9.2
Land Use Control	3.0	1.1	4.0	7.9
Expanded Soundproofing Zone	3.0	1.1	4.0	7.9

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[a] Baseline refers to year 2000 demographics; land use control and expanded soundproofing refer to year 1990 demographics.

VI. RELOCATION COSTING PROCEDURE

This chapter describes the framework from which the relocation costs described in Chapter IV were developed. The type of assistance which may be offered in a given relocation program is modeled after the requirements of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, 42 U.S.C. 4601. Although there would be instances in which the Act must be applied due to Federal participation in the project, it is anticipated that there will be many cases in which the Federal Government would not be involved and in these instances the Act may be used as a helpful guide in program planning.

The framework begins with an overview of the applicability and requirements of this Act. Next a set of relocation cases is defined and a procedure to estimate the frequency of each case is set forth. Finally, costs associated with each program element covered by the cases are presented.

UNIFORM RELOCATION ACT REQUIREMENTS

Enacted in 1971, the Relocation Act was a Congressional response to problems caused by differing and conflicting provisions for relocating displaced persons inherent in a wide range of federally-assisted programs. These programs ranged from providing no assistance at all in some cases to providing liberal benefits and protection in others. The Act was directed at resolving these inequities by establishing a uniform policy for the fair and equitable treatment of persons displaced as a result of Federal and federally-assisted programs.

Whether the Relocation Act would actually apply for an airport soundproofing/relocation program remains an open question. Applicability centers around the meaning of Section 101(6) of the Act which defines "displaced person". It is this definition that governs eligibility for the several types of assistance availabe under the Act. Section 101(6) provides, as pertinent, that:

> The term "displaced person" means any person who... moves from real property, or moves his personal property from real property, as a result of acquisition of such real property, in whole or in part,... for a program or project undertaken by a Federal agency, or with Federal financial assistance;....

Section 108 of the Act extends relocation coverage to state agencies whenever such agency acquires real property "...at the request of a Federal agency for a Federal program or project..." In such instances, the acquisition for the purpose of the Act shall be deemed an acquisition by the cognizant Federal agency. A state agency is defined in Section 101(3) as:

> ...any department, agency, or instrumentality of a State or of a political subdivision of a State, or any department, agency, instrumentality of two or more States or two or more political subdivisions of a State or States.

Coverage of a displaced person thus requires that there be extant a clear Federal involvement (in the form of financial assistance or a program or project) and that the acquisition be undertaken directly by a Federal agency or through a political instrumentality of a state.

The Federal Government may be involved in the program under three broad mechanisms. The first is direct grants and loan guarantees to individual airports, such as those under the Federal Aviation Administration's Airport Development Aid Program (ADAP) or Federal-aid to Airport Program (FAAP). Even partial funding would bring the program under the first test of applicability of the Act as long as such funds are used specifically for the acquisition of residences and relocation of profile.

The second mechanism arises if the overall program would come under some degree of direct Federal Government direction or control. An example scenario would have noise charges collected by individual airports transferred to the Federal Government and then allocated to airport programs depending on their need. This hypothetical process is similar to the Highway Trust Fund which allocates funds to various State highway departments. As long as funds finance identified airport programs, the first test would be met.*

The final mechanism would occur where the Federal Government would possibly suggest standards and time limitations for program implementation, but would not be involved in allocating funds collected by individual airports as discussed in the case above. While a Federal "presence" would be extant, persons would not displaced as a result of a program or project undertaken by a Federal agency nor would Federal financial assistance be involved.

From the above discussion, it is evident that, while it is certainly possible that the Relocation Act could apply to airport-specific relocation/soundproofing programs, conclusions regarding the extent of its coverage are not possible at this time. The Act nevertheless provides a useful basis from which relocation costs can be developed. This is done by first defining a set of discrete relocation cases and then determining costs for each case.

ALLOWABLE COSTS

Persons displaced under the Relocation Act are entitled to assistance and cost reimbursement in three categories as follows:

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*A possible exception would be if the fund transfers were characterized as "block grants" with virtually no strings attached. This situation could be analogous to general revenue sharing funds allocated pursuant to the State and Local Fiscal Assistance Act of 1972, 31 U.S.C. 1221 et seq. These funds transfer have been held to be exempt from the Relocation Act because of the Act's requirements and the "no strings attached" intent of general revenue sharing.

- Relocation assistance advisory services -- a program element funded by the relocation agency to provide general assistance to displaced persons

- Direct payments not subject to statutory limitations - homeowners and tenants are entitled to reimbursement for actual reasonable moving expenses and homeowners are entitled to the fair market value for acquired property.

- Direct reimbursements subject to statutory limitations - reasonsable costs associated with securing replacement housing subject to a maximum of $15,000 for homeowners and 4,000 for tenants.

The basic cost elements of the three categories are summarized in Table 6.1 and are discussed in more detail below.

DEFINITION OF RELOCATION CASES

Four relocation cases are defined as follows:

- Case A -- Renters who remain renters
- Case B -- Renters who become homeowners
- Case C -- Rental property to be purchased
- Case D -- Owner-occupied units to be purchased.

Relocation cost elements applicable to each case are summarized in Table 6.2 The cases are discussed below.

Renters Who Remain Renters

The first case is comprised of existing renters who elect to remain renters. Section 204 of the Act provides for payments to tenants in displaced dwellings who were tenants for at least 90 days prior to the initiation of negotiations for acquisition of such dwellings. These persons are entitled to a rent supplement for up to four years in the event that the rent in a

TABLE 6-1

ASSISTANCE AND COST REIMBURSEMENT ITEMS UNDER THE RELOCATION ACT

DESCRIPTION	ACT REFERENCE	COMMENTS
ADVISORY SERVICES	Sec. 205	• Available to displaced persons and adjacent property owners • Covers property appraisal, locating replacement housing, agency administrative expenses, etc.
DIRECT PAYMENTS WITH NO LIMITATIONS		
• Moving expenses	Sec. 202	• Actual, reasonable expenses • Moving ($300) and dislocation ($200) expenses allowance in lieu of actual expenses
• Purchase Price	Sec. 203	• Fair Market Value (FMV) of dwelling acquired • Limited to homeowners.
DIRECT PAYMENTS WITH LIMITATIONS		
• Replacement Costs (Homeowners)	Sec. 203	• Difference between purchase price of replacement dwelling and FMV of dwelling acquired

TABLE 6-1 (Cont.)

DESCRIPTION	ACT REFERENCE	COMMENTS
• Increased Interest Cost	Sec. 203	• Interest differential between acquired and replacement dwelling (homeowners with hona fide mortgage).
• Closing Cost	Sec. 203	• Reasonable expenses for evidence of title, recording fees, and closing costs related to replacement dwelling (homeowners only).
• Downpayment	Sec. 204	• Tenants purchasing replacement housing (not to exceed $4,000, with displaced person matching payments in excess of $2,000).
• Replacement Costs (Tenants)	Sec. 204	• Lease or rental differential between acquired and replacement rental dwelling.
• Income Foregone	Sec. 202	• Compensation to owners of rental property, subject to $10,000 maximum.

TABLE 6-2
COST ELEMENTS AND RELOCATION COSTS

COST ELEMENT	RELOCATION CASE*			
	A	B	C	D
Advisory Service Cost	X	X	X	X
Moving Cost	X	X		X
Purchase Price			X	X
Replacement Cost	X			X
Increased Interest Cost				X
Closing Cost				X
Downpayment		X		
Foregone Earnings			X	

*Relocation Cases

A. Renters Who Remain Renters
B. Renters Who Become Homeowners
C. Rental Property to be Purchased
D. Owner-Occupied Units to be Purchased

replacement unit exceeds the rent the displaced person is paying at the time of relocation. Such payments may not exceed $4,000. Renters are also entitled to the advisory services of the local relocation agency (Section 205) and to re-imbursement for moving expenses.

Renters Who Become Homeowners

The Relocation Act recognizes that renters who are dislocated may want to purchase their own homes as an option to moving to another rental property. These people are entitled to the advisory services of the relocation agency and re-imbursement for moving expenses. In addition, there is a special provision in Section 205 of the Relocation Act making money available for down-payments (including incidential expenses) on replacement homes. Such payments shall not exceed $4,000, except that the renter must match any amount paid in excess of $2,000.

Rental Property To Be Purchased

The third relocation case is made up of rental property to be purchased. Owners of these properties are entitled to the fair market value of their rental units. Because landlords typically suffer a disruption of their business operations and lose their existing tenants in the course of the relocation, they may elect to accept a compensatory payment to cover the cost of their foregone earnings from the rental units. Such payments are distinct from payments to dislocated renters addressed under the prior two cases.

Owner-Occupied Units To Be Purchased

The fourth and most complex relocation case is made up of owner-occupied units to be purchased. It is assumed that the owners of these units will remain homeowners even though some will, in fact, choose to become renters. This simplifying assumption may result in a slight overestimate of the relocation cost of homeowners.

Relocated homeowners are entitled to the services of the relocation agency and re-imbursement for moving costs. The homeowners are also entitled to the purchase price (at fair market value) of their homes and a supplemental payment over and above the fair market value in the event that the purchase price of the comparable replacement home exceeds the fair market value of their homes in the area exposed to excessive airport noise. They are also entitled to compensation for any increased interest costs resulting from liquidating the original mortgage and taking out a new mortgage on the replacement dwelling at the current mortgage interest rate, and any closing costs involved in the purchase of the replacement home.

CASE FREQUENCIES

The procedures described here for estimating relocation case frequencies rely almost exclusively on the output of the ALAMO program (Reference 1) as modifed by the updating procedures in ORI's DEMCOM program (see Reference 2 and prior discussion in Chapter IV). A sample output from DEMCOM is provided in Figure 6.1 for reference purposes (in particular, note the frequency data on the numbers of households, renters, homeowners and housing units).

Renters Who Remain Renters

The total number of renters residing within the L_{dn} 75+ dB contour in year 1979 for the Rport represented by Miami International Airport is 2,837 (see Figure 6.1). Should these renters avail themselves of the relocation option, they may choose under the Relocation Act to either remain renters (Case A) or become homeowners (Case B). The mix between Case A and Case B was based on a survey of the U.S. Department of Transportation's Federal Highway Administration (FHWA) experience under the Relocation Act (Reference 3). A survey 2,473 tenants relocated during Fiscal Year 1979 resulted in 2,086 claims which did not involve downpayment assistance. Thus, 84 percent of affected tenants chose to remain renters. This percentage is used as a constant for all relocation frequencies examined in this report. For Miami, the frequency of Case A is 2,383 (or 2,837 x .84).

Renters Who Become Homeowners

The FHWA survey mentioned immediately above resulted in 16 percent of affected tenants filing claims under the Relocation Act for downpayment assistance. This percentage is similarly applied to relocation frequencies. For Miami, the frequency of Case B is thus 454 (or 2,837 x .16).

Rental Property to be Purchased

Noting again Figure 6.1, there were 3,582 residential housing structures located in the potential relocation zone. These structures range from a single building of more than 50 units to some 3,144 single-unit dwellings. It is assumed for purposes of this study that rental properties consist of all structures minus those occupied by homeowners, who are further assumed to all reside in single-unit dwellings. The number of rental properties subject to purchase (Case C) under the Relocation Act is thus 1,399 (or 3,582 - 2,183).

Owner-Occupied Units to be Purchased

The final classification (Case D) consists of owner-occupied units which would be eligible for purchase under the Relocation Act. This is assumed to be comprised of the total number of homeowners from Figure 6.1 or 2,183.

RELOCATION ELEMENT COSTS

Estimates are presented in this section for cost elements comprising each relocation case in 1979 dollars. Certain costs (such as those for advisory services, moving costs and closing costs) are constants which apply to all Rports and all scenarios. Others are dependent upon localized demographic conditions and therefore vary across Rports and scenarios. Examples include purchase price and replacement costs for properties relocated. Much of the data needed to calculate airport-specific element costs are provided as direct output of ORI's DEMCON program. A sample output page is provided in Figure 6.1 for the Rport represented by Miami International

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Airport, updated for 1979 values and 1979 baseline air carrier operations and for the L_{dn} 75+ dB contour. References to costs associated with this Rport are provided for added clarity to the description of cost element derivation provided below.

Advisory Service Costs

Advisory service costs are costs incurred by the relocation agency. They cover such activities as appraisal, negotiations, relocation assistance and administration. They may also include the cost of locating and appraising three or more comparable replacement housing units for each unit to be vacated. This activity is recommended by the Relocation Act and is used to determine the reasonable cost of replacement housing and to provide the dislocated households with alternatives. The households may reject the alternatives and find their own replacement housing but they will be subject to the "reasonable cost" estimates of the relocation agency. In 1979, the service costs of relocation incurred by the Federal Highway Administration (Reference 3) averaged $1,200. This constant is used for all cases.

Moving Costs

Moving costs are incurred by all relocated households. Under the Relocation Act, households may be compensated for actual costs or may elect to receive a fixed allowance. Under the Act, all moves are local or treated as if they were local. In 1979, eighty-four percent of all households relocated by the Department of Transportation chose to receive the moving allowance plus dislocation allowance totaling $500 per household or less. The remainder were compensated for actual costs which averaged $1,200 a household. The average moving cost per household in 1979 was approximately $500. This value is also constant for all cases.

Closing Costs

Closing costs are incurred by all persons making a home purchase. In 1979 the Department of Transportation reported that closing costs associated with relocation averaged $400 per unit. Closing costs are low because the relocation agency provides guarantees to lending institutions and acts, to some extent, as legal representative for the relocated households. Also, all households participating in the relocation program are typically exempt from all taxes associated with the sale of their original units and the purchase of the replacement units. A constant $400 is used for all cases.

Downpayment

The Federal Relocation Act has a special provision designed to assist tenants in becoming homeowners. Specifically, $2000 is available outright to tenants for use as a downpayment and an additional $2000 is available on a matching basis. It is assumed that each tenant electing this option has at least $2000 to put toward a downpayment and, therefore, is eligible for the full $4000 downpayment allowance.

Replacement Cost

Relocated tenants and homeowners receive a payment to cover the increased rental or purchase price required to obtain comparable replacement housing in a quieter neighborhood. Airports exert two distinct effects on residential land values: a depreciation effect due to aircraft noise and an appreciation effect due to accessibility to the airport (Reference 4). The Relocation Act requires that replacement housing be equally accessible to places of employment. Since the airport is an employment center, replacement housing is assumed to be equally accessible to the airport so that the appreciation in residential property values due to access cancels out, leaving only the depreciation effect due to noise.

Regarding the decrement in rents and property values due to noise exposure, residential rents and property values are assumed to decline by one half of one percent per decibel of noise exposure, holding distance to the airport constant (Reference 5).

It is further assumed that a typical relocation within the greater than L_{dn} 75 dB contour would move from an area of average noise exposure of L_{dn} 77.5 dB to an area with an average exposure of L_{dn} 62.5 dB.* This relocation involves an increase in residential rents and property values of 7.5 percent (0.5 x 15).**

While the decrement percent is constant for all Rports, the actual value for replacement housing varies by Rport based on average rent and home values. Under the Relocation Act tenants are eligible to a lump sum payment equal to four times the increase in their annual rent. For the Rport represented by Miami International, the average rent in 1979 is $198 per month or $2,376 per year. The relocation involves an increase in rents of 7.5 percent or $178.20 per year. Four times this is $713, the average replacement cost for tenants.

The average home value for the Miami Rport is $31,658. The relocation involves moving to a comparable house in a quieter neighborhood where homes cost 7.5 percent more, or an incremental replacement cost of $2,374.***

Purchase Price of Owner-Occupied Units

The homeowners displaced as a result of an airport relocation effort are entitled to the fair market value for purchased properties. The average home value in 1979 dollars for the Miami Rport is $31,658.

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*The latter area was chosen to reflect property in the general vicinity of an airport but exposed to noise levels below L_{dn} 65 dB which would make the property a candidate for soundproofing assistance. Stated somewhat differently, a reasonable goal of a program would be to offer positive relief to affected residents and not to merely transfer a family between areas affected by adverse airport noise levels.

**The increase could be 10.0 percent for relocations from a L_{dn} 80+ dB contour.

***The Relocation Act's $15,000 limit on replacement dwelling has not been raised in 10 years, even in the face of rapidly escallating housing values during this period. However, Federal agency experience under the Act is that payments generally do not exceed this limit. This situation may have changed in the last few years due to the extremely high interest rates.

Purchase Price of Rental Property

Under the Relocation Act all owners who must vacate their dwellings are entitled to receive fair market value for their residential property. From information on the monthly rental, an estimate of the fair market value of the typical rental property is derived. The formula used is:

$$C = \frac{12(RU)}{i} \qquad (1)$$

where: C = fair market value of a typical rental property in a given year

R = monthly rental income from a typical rental unit in that same year

U = average number of units per rental property

i = estimated mortgage interest rate in that year.

Equation (1) is a simplification of a complex relationship in that it ignores capital gains, depreciation, maintenance costs, taxes and anticipated changes in rents and interest rates.* It is assumed that these complicating factors tend to offset one-another so that Equation (1) provides an estimate of the present value of rental property which is adequate for the purpose of making cost estimates.

The average rent (R) in 1979 for the Miami Rport is \$198 per month or \$2,376 per year. The average number of units per rental property (U) within the L_{dn} 75+ dB contour is estimated by subtracting the number of homeowners (who are assumed to occpy single-unit structures) from total airport units and then dividing by the total number of structures, less the number of homeowners. The equation is:

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*See Appendix D of Reference 6 for the procedure used in Equation (1) in mathematical notation.

$$U = \frac{x - y}{z - y} \tag{2}$$

where x = total number of residential units
y = total number of homeowners
z = total number of residential structures.

Derivation of the mortgage interest rate (i) for the relocation year presents special problems due to year-to-year fluctuations in the rate. Because the costing procedure is intended to be representative of all relocation cases in all scenario years, the actual mortgage interest rates prevailing in the year of sale are not used. Instead, rates are used from which unwanted year-to-year fluctuations have been removed. These "smoothed out" rates better represent the linear trend in interest rates over the 25 year period 1955-1979. The time series data for this period are listed in Table 6.3 and plotted in Figure 6.2. Also shown in Figure 6.2 is the least square line fitting the data. This line is used to estimate the trend-line mortgage interest rates for the historical period and for the forecast years. Thus,

$$i = 0.048 + 0.00196Y \tag{3}$$

where:
i = mortgage interest rate in year Y
Y = year analyzed with 1955=0 (e.g., if relocation occurs in year 1979, then Y = 24).

Applying Equations (1) to (3) to the Miami Rport results in an average rental property purchase price of $55,472.

Increased Interest Cost

The increased interest cost occurs when the interest rate on the replacement mortgage exceeds the interest rate on the original mortgage. To insure that the relocation does not impose a financial burden on the relocated homowner, special compensation is made to offset the increase in interest rates. No compensation is required if there is nc increase in interest rates or if the acquired property is not encumbered by a bona fide mortgage.

For convenience, the provisions of the Relocation Act dealing with increased interest costs are provided below:

> The amount, if any, which will compensate such displaced person for any increased interest costs which such person is required to pay for financing the acquisition of any such comparable replacement dwelling. Such amount shall be paid only if the dwelling acquired by the Federal agency was encumbered by a bona fide mortgage which was a valid lien on such dewlling for not less than one hundred and eighty days prior to the initiation of negotiations for the acquisition of such dwelling. Such amount shall be equal to the excess in the aggregate interest and other debt service costs of that amount of the principal of the mortgage on the replacement dwelling which is equal to the unpaid balance of the mortgage on the acquired dwelling, over the remainder term of the mortgage on the acquired dwelling, reduced to discounted present value. The discount rate shall be the prevailing interest rate paid on savings deposits by commercial banks in the general area on which the replacement dwelling is located.

Given the amount remaining on the original mortgage, the number of monthly payments remaining, the original mortgage interest rate and the mortgage interest rates in effect in the year of the relocation, the increased interest cost is calculated as follows:

$$I = \frac{A-B}{C} D \qquad (4)$$

where: I = increased interest cost
A = monthly payment based on new interest rate
B = monthly payment based on original interest rate
C = monthly payment based on passbook savings interest rate
D = outstanding balance on old mortgage.

The year in which the homeowner purchased his home, and the interest rate in effect in that year, are crucial to the determination of increased interest cost. Some homes in the relocation area may have been purchased recently at relatively high interest rates. Others may have been purchased long ago at the low interest rates prevailing at that time. This complex reality may be approximated with a single representative case. Specifically, the following assumptions apply to all purchased homes:

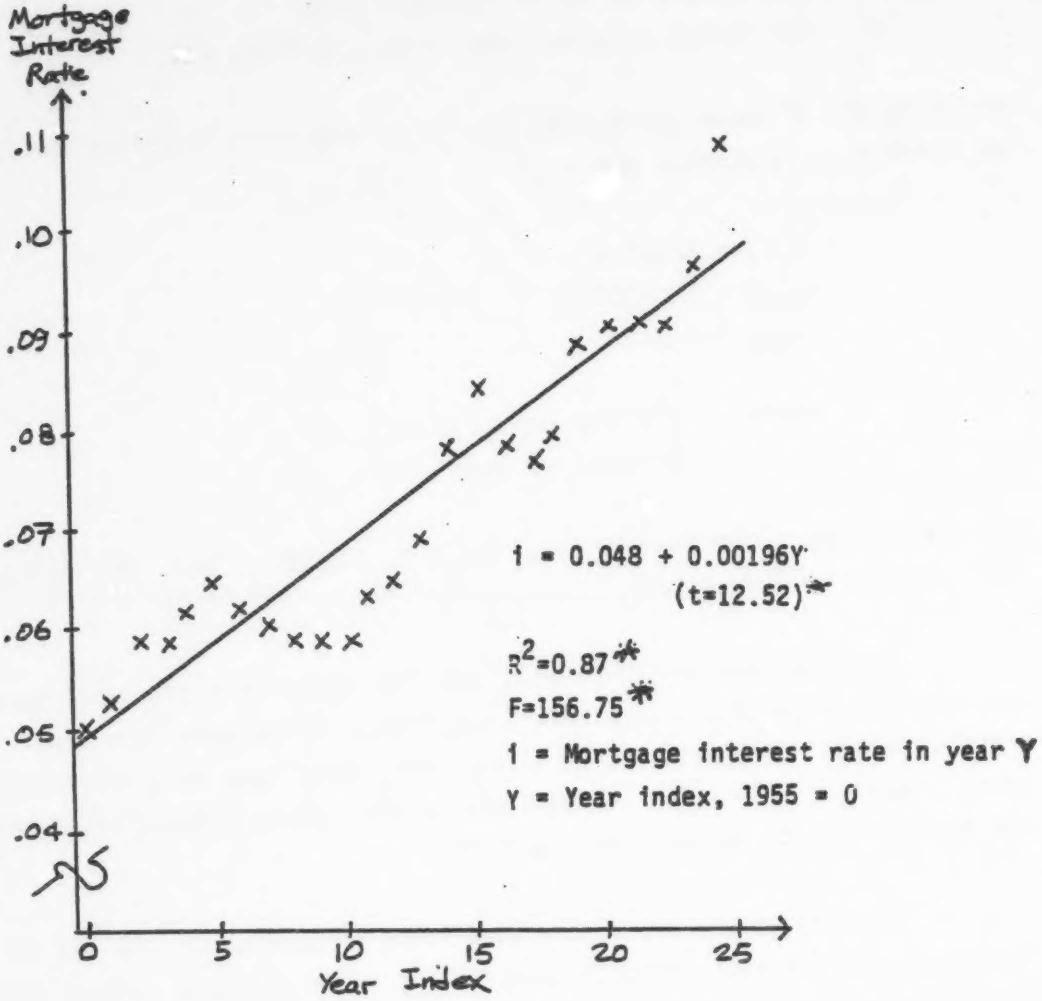
TABLE 6.3

ACTUAL AND ESTIMATED MORTGAGE INTEREST RATES FOR THE YEARS 1955-1979

YEAR	YEAR INDEX	ACTUAL RATE	ESTIMATED RATE
1955	0.0	0.0500	0.0483
1955	1.0	0.0530	0.0503
1957	2.0	0.0590	0.0523
1958	3.0	0.0580	0.0542
1959	4.0	0.0620	0.0562
1960	5.0	0.0640	0.0581
1961	6.0	0.0610	0.0601
1962	7.0	0.0600	0.0621
1963	8.0	0.0589	0.0640
1964	9.0	0.0582	0.0660
1965	10.0	0.0851	0.0680
1966	11.0	0.0625	0.0699
1967	12.0	0.0646	0.0719
1968	13.0	0.0697	0.0738
1969	14.0	0.0780	0.0758
1970	15.0	0.0845	0.0778
1971	16.0	0.0774	0.0797
1972	17.0	0.0760	0.0817
1973	18.0	0.0795	0.0836
1974	19.0	0.0892	0.0856
1975	20.0	0.0901	0.0876
1976	21.0	0.0899	0.0895
1977	22.0	0.0901	0.0915
1978	23.0	0.0954	0.0934
1979	24.0	0.1077	0.0954

Source: 1955-1962, The Data Resources U.S. Long-Term Review, Winter 1977, Data Resources, Inc., "Housing," pages 11.10 - 11.11

1963-1979, Economic Report of the President, Transmitted to the Congress, January 1980, Table 64, page 278



$i = 0.048 + 0.00196Y$
$(t=12.52)^*$

$R^2=0.87^*$
$F=156.75^*$

i = Mortgage interest rate in year Y

Y = Year index, 1955 = 0

FIGURE 6.2

SCATTER DIAGRAM OF MORTGAGE INTEREST RATES AND THE LEAST SQURES REGRESSION LINE, 1955-1979

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*The F statistic and student's t statistic indicate that the regression and the coefficient of the year index are quite significant. The R^2 indicates that the regression accounts for 87 percent of the variance in mortgage interest rates over time.

- Mortgage duration at original purchase is 25 years
- Mortgage 10 years old at time of relocation (15 years remaining)
- Passbook saving rate of 5.25 percent
- Downpayment of 10% of purchase price
- Smooth-out interest rates used (See Table 6.3).

Combining all of these assumptions lead to a simplified equations for three representative relocation years:

$$I_{1979} = 0.050414\ E \tag{5}$$
$$I_{1990} = 0.114828\ E \tag{6}$$
$$I_{2000} = 0.124469\ E \tag{7}$$

where: I = increased interest cost
E = average home value.

The average home value for the Miami Rport is $31,658. Thus, the increased 1979 interest cost is $1,596.

Equations (5) to (7) coupled with the assumptions presented earlier are intended to provide a straight-forward means to estimate increased interest costs. An approximation of the costs associated with relocation years other than 1979, 1990 and 2000 may be obtained by extropolating between the constant values in the three equations.

Critical to the use of the simplified methodology is the use of the "smoothed out" interest rates in equation (3) and Figure 6.2. Drastically different results are obtained when year-to-year fluctuations in mortgage interest rates are considered. For example, suppose that a "relocatee" had purchased his home 10 years before the time of relocation. At that time he took a mortgage of $50,000 with a term of 25 years at an interest rate of 9% per year. His monthly payment would be $419.60. At the time of relocation the unpaid balance on his mortgage would be $41,369.62. When the relocatee purchases a new home he is compensated for any additional interest costs incurred by his having to borrow $41,369.62 at a higher rate of interest for 15 years (the time his first mortgage had to run). Assuming that the interest rate at the time of relocation is 16% per year. The relocatee would have to pay $607.60 per month in order to liquidate his debt in 15 years. This is $607.60 - $419.60 or $188.00 per month more than he had been paying prior to relocation. The present value of this annuity at "the prevailing interest rate paid on savings deposits by commercial banks in the general area in which the replacement dwelling is located" for a period of 15 years is the compensation paid the relocatee for increased interest cost. In the present case, a bank interest rate of 5.5% per year is assumed. This gives $23,008.66 as the amount the relocatee would receive.

The increased interest cost of $23,000 in the above example is considerably higher than the $1,596 estimate provided previously. This report is predicated on the later estimate on the assumption that the current (1981/1982) mortgage interest rates are the results of abnormal economic conditions and the rapid increase in rates is not likely to be representative of long term conditions and trends. The reader is referred to Appendix F of Reference 6 for derviation of interest costs based on actual mortgage rates and terms.

Income Foregone

Landlords typically suffer a disruption of their business operations and lose their existing tenants in the course of the relocation. However, the replacement properties which they purchase are typically occupied at the time of purchase. Under the Federal Relocation Act, owners of multiple unit structures receive the difference in gross annual earnings, if any. The owners of such units are also entitled to compensation for moving costs, up to $1,000, and search costs, up to $500.

Owners of single unit rental structures who purchase comparable replacement structures are entitled to receive as compensation an amount equal to their average annual net earnings from their original rental property, if not less than $2500 nor more than $10,000. This payment is in lieu of moving costs and search costs. For simplicity, it is assumed that all owners of single unit rental property receive an amount equal to their average annual net earnings. It is further assumed that net earnings equal three-quarters of gross earnings The average rental income in 1979 for the Miami Rport is $2,376 per unit per year. The net rental income is 75 percent of this, or $1,782 per single unit rental property.

The owners of multi-unit rental property receive a flat payment of $1,500 plus compensation for loss in gross earnings. It is assumed that such owners experience no loss in gross annual earnings and therefore receive $1,500. This payment is made without regard to the number of rental units in their buildings. To place income foregone costs on a per-rental property basis, the distribution of rental units among single and multi-unit structures must be known. This can be derived from the data in Figure 6.1 as follows. First, single-unit rentals equal single unit structures (3,144) less homeowners (2,183), or 961. Multi-unit rentals are simply total structures (3,582) less single-unit structures (3,144), or 438. From this example, 69 percent of all rental properties are single-unit properties and 31 percent are multiple-unit properties. Thus, the average income foregone per rental property is 0.69 times $1,782 plus 0.31 times $1,500, or $1,694 per rental property.

Relocation Element Cost Summary

Table 6.4 presents a summary of all relocation cost elements for the Miami Rport. Costs associated with the four relocation cases presented earlier are also presented. Note that the procedures described herein are concerned with gross costs. They do not reflect value which may be received from salvage of purchased properties or from subsequent resale of the land. Benefits of these and similar transactions are discussed in Chapter II, Issue Analyses.

TABLE 6-4

RELOCATION COSTS PER CASE ($1979): (MTA) MIAMI, FL
BASELINE 1979 OPERATIONS

COST ELEMENT	RELOCATION CASE*			
	A	B	C	D
ADVISORY SERVICE COST	1200.	1200.	1200.	1200.
MOVING COST	500.	500.		500.
PURCHASE PRICE			55472.	31658.
SUB-TOTAL1	1700.	1700.	56672.	33358.
REPLACEMENT COST	713.			2374.
INCREASED INTEREST COST				1596.
CLOSING COST				400.
DOWNPAYMENT		4000.		
INCOME FOREGONE			1694.	
SUB-TOTAL2	713.	4000.	1694.	4370.
TOTAL COST PER CASE ($)	2413.	5700.	58366.	37728.
FREQUENCY OF CASE	2383.	454.	1399.	2183.
TOTAL ($MILLIONS)	5.75	2.59	81.65	82.36
GRAND TOTAL ($MILLIONS):	172.35			

*RELOCATION CASES
- A. RENTERS WHO REMAIN RENTERS
- B. RENTERS WHO BECOME HOMEOWNERS
- C. RENTAL PROPERTY TO BE PURCHASED
- D. OWNER-OCCUPIED UNITS TO BE PURCHASED

REFERENCES

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2. ORI, Inc., User's Manual for the ALAMO Demographic Report Generator Program, September 1981.

3. U.S. DOT, Office of Right-of-Way, Federal Highway Administration, personal correspondence to ORI, January 23, 1981.

4. Modig, C. et. el., Trends in the Literature on: The Effect of Aircraft and Traffic Noise on Residential Property Values, Informatics, Inc., October 1980.

5. Nelson, J. P., "Airports and Property Values" A Survey of Recent Evidence", Journal of Transport Economics and Policy, January 1980.

6. Felder, J., Procedures to Estimate Airport Residential Relocation Costs, ORI Technical Report No. 1856, April 1981.

APPENDIX A

SPOUNDPROOFING/RELOCATION PROGRAM EXPOSURE SUMMARIES

TABLE A-1 AIRPORT-NOISE-EXPOSURE REDUCTION AND COSTS

Miami, FL (MIA)

Year and Airport Scenario	Population Exposed L_{dn} 65-75 dB	Over L_{dn} 75 dB	Soundproofing, Relocation Cost[a]	Population Exposed L_{dn} 65-80 dB	Over L_{dn} 80 dB	Soundproofing, Relocation Cost[a]
1979						
O-R*	216,000	13,100	336,600	227,800	1,300	185,200
1-FP	125,600	22,200	399,400	146,000	1,800	179,900
2-FT	63,800	4,300	192,900	68,100	2,800	93,200
1990						
O-R	166,100	7,200	221,500	171,900	1,400	170,000
1-FP	110,000	11,900	247,300	120,200	1,700	140,400
3-RD[b]	142,900	6,100	183,100	147,800	1,200	138,800
4-RD+FP	96,000	11,400	228,400	105,900	1,500	122,500
5-RD+FT[b]	42,200	5,300	94,900	44,500	3,000	74,600
2000						
O-R	95,900	2,500	109,800	96,700	1,700	104,500
3-RD	69,100	1,700	73,500	69,600	1,200	70,300
5-RD+FT	20,400	1,500	33,700	20,800	1,100	29,200

* R - Reference data base
FP - Flight procedure, FAA AC 91-53, maximum thrust reduction
RD - Residential development restricted to prevent encroachment after 1979 (land use)
FT - Selected flight tracks and priority runway use

a - Cost in Constant 1979 Dollars/1000.
b - Interpolated, 1979 - 2000

TABLE A-1 - CONTINUED. AIRPORT-NOISE-EXPOSURE REDUCTION AND COSTS

LaGuardia, NY (LGA)

Year and Airport Scenario	Population Exposed L_{dn} 65-75 dB	Population Exposed Over L_{dn} 75 dB	Soundproofing, Relocation Cost_a	Population Exposed L_{dn} 65-80 dB	Population Exposed Over L_{dn} 80 dB	Soundproofing, Relocation Cost_a
1979						
O-R*	1,337,300	83,600	1,374,000	1,403,300	171,600	839,100
1-FP	736,600	112,500	1,377,600	822,000	27,100	610,800
2-FT	961,000	40,200	794,100	990,800	10,400	565,900
1990						
O-R	811,100	46,800	804,700	851,500	6,400	483,700
1-FP[b]	440,400	61,600	757,600	487,700	14,300	355,800
2-FT	563,400	21,900	454,300	581,700	3,600	314,900
2000						
O-R	171,100	15,300	195,600	183,700	2,700	124,000
2-FT	123,800	7,000	109,200	129,200	1,600	84,400

* R - Reference data base
FP - Flight procedure, FAA AC 91-53, maximum thrust reduction
RD - Residential development restricted to prevent encroachment after 1979 (land use)
FT - Selected flight tracks and priority runway use

a - Cost in constant 1979 dollars/1000.
b - Interpolated, 1979 - 2000

TABLE A-1 - CONTINUED. AIRPORT-NOISE-EXPOSURE REDUCTION AND COSTS

Year and Airport Scenario	San Antonio, TX (SAT) Population Exposed L_{dn} 65-75 dB	San Antonio, TX (SAT) Population Exposed Over L_{dn} 75 dB	San Antonio, TX (SAT) Soundproofing, Relocation Cost[a]	Sioux Falls, SD (FSD) Population Exposed L_{dn} 65-75 dB	Sioux Falls, SD (FSD) Population Exposed Over L_{dn} 75 dB	Sioux Falls, SD (FSD) Soundproofing, Relocation Cost[a]
1979						
O-R*	64,240	1,590	52,500	2,640	900	7,880
1-FP	42,000	3,860	95,800	3,730	890	7,670
2-FT	24,650	10	15,900	90	890	5,590
1990						
O-R	40,350	1,640	63,600	3,030	1,070	7,890
1-FP	41,820	1,850	68,900	3,530	1,090	7,890
3-RD[b]	28,980	1,360	47,900	2,640	890	6,640
4-RD+FP	31,000	1,840	56,500	3,140	890	6,670
5-RD+FT[b]	11,120	10	9,900	90	800	5,050
2000						
O-R	41,650	30	44,400	3,360	1,280	8,350
3-RD	21,000	10	20,700	2,590	890	5,940
5-RD+FT	8,070	0	7,900	90	800	5,020

* R - Reference data base
FP - Flight procedure, FAA AC 91-53, maximum thrust reduction
RD - Residential development restricted to prevent encroachment after 1979 (land use)
FT - Selected flight tracks and priority runway use

a - Cost in constant 1979 dollars/1000.
b - Interpolated, 1979 - 2000